M. ILIN

100,000 WHY'S

A TRIP AROUND THE ROOM

100,000 WHYS

A Trip Around the Room

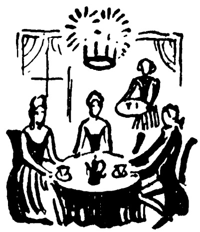
M. ILIN, who wrote New Russia's Primer, Black on White, *and* What Time Is It? *is a young Russian engineer, brother of Marschak, the famous Russian poet and story-teller. Both brothers belong to a group of writers who are studying science and history and Soviet life and writing books not only for Russian children but for workers in factories and for peasants. Some of the members of this group are artists, one used to be a cook in the Red Army, two are former homeless children. All of them work together trying to make simple stories about the real world we live in.*

100,000 WHYS

A Trip Around the Room

M. ILIN

Translated by Beatrice Kinkead



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100,000 WHYS

A Trip Around the Room

A TRIP AROUND THE ROOM

> "Five thousand WHERES, seven thousand HOWS, a hundred thousand WHYS."
>
> Rudyard Kipling

EVERY day somebody in your house starts the fire, heats water, boils potatoes.

Maybe you know all about starting the fire or boiling potatoes. But see if you can tell me why the wood crackles when it burns? Why smoke goes up the chimney instead of coming out into the room? Where the soot comes from when you burn kerosene? Why baked potatoes have a crust and boiled ones have not?

I'm afraid you couldn't give very satisfactory explanations.

Or try this one: Why does water put the fire out?

One of my young friends said: "Because it's wet and cold."

Yes, but you know kerosene is also wet and cold, but just try putting out a fire with kerosene. No, you'd better not try it. You might have to call in the fire department.

You see, that's a simple question, but it's not so easy to answer.

Do you want to hear twelve riddles about the most ordinary things?

1

Which is warmer, three shirts or one shirt three times as thick?

2

Can you make walls of air?

3

Does fire cast a shadow?

4

Why doesn't water burn?

5

Can you blow up a house with water?

6

Why does the stove make so much noise when a fire is lighted in it?

7

Why do we blow on a match when we want to put it out?

8

Is there such a thing as transparent iron?

9

Why are there holes in bread?

10

A stove warms us because there is fire in it. Why does an overcoat keep us warm?

11

Why do we put a damp cloth over woolens when we press them?

12

Why can you skate on ice but not on the floor?

Hardly one reader in ten can answer these questions. We know very little about the things about us. And often there is no one to ask. You can get plenty of books about steam engines, or about telephones, but where will you find a book about baked potatoes or stove pokers? There are such books, but one has to read through an enormous number of them to find the answers to even these twelve riddles.

Yet one might ask a hundred thousand such questions instead of only twelve. Everything in the room is a riddle. Of what is it made, and why? When was it invented?

Take a table knife and fork, for instance. They are always together like a brother and sister. But do you know that the knife is at least a hundred thousand years older than the fork? The very earliest people had knives. Not iron ones, it is true, but stone.

Whereas forks came into use not more than three hundred years ago at the earliest.

People know when and by whom the telephone and the electric lamp were invented, but just ask them when mirrors were invented, or handkerchiefs, or when people began using soap for washing, or how long we have been eating potatoes. Very few people will be able to answer you.

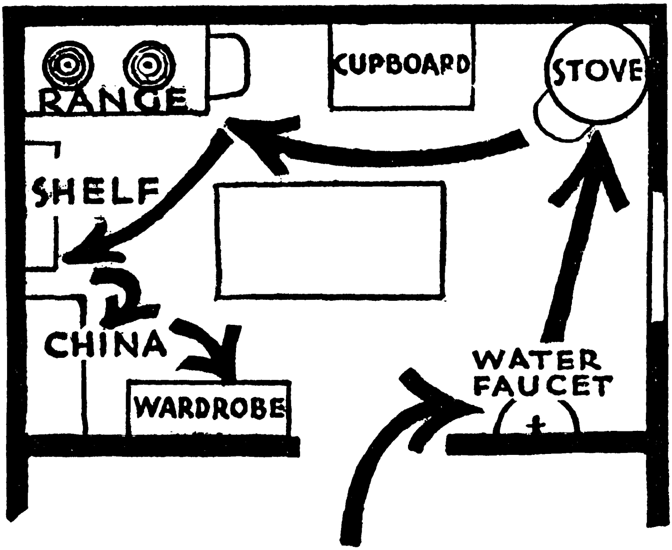
We love to read about expeditions to remote, unexplored countries. Yet we never suspect that within two feet of us, or maybe even nearer, there is a wonderful, unexplored, mysterious country called:

Our Room

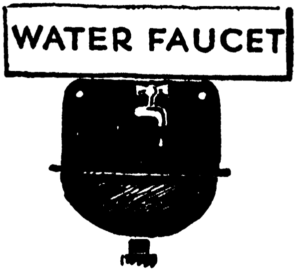
If we want to explore this country we may set out on the trip at any moment. And we shan't have to have any folding cots or guns or guides either. We don't even need a map. We shall be in no danger of losing our way.

Here are the stations:—Water Faucet. Heating Stove. Cupboard and Range. Shelf for saucepans. China Closet. Wardrobe.

A TRIP AROUND THE ROOM



The Room We Explore



STATION ONE
THE WATER FAUCET

When did People First Begin to Wash Themselves?

THERE are very few cities nowadays without water systems. Every one of us uses about ten or twelve pails of water a day. But in olden times an inhabitant of a large city used only about one pailful. Just figure out how often they could wash and how much water they could use for washing clothes and scrubbing rooms!

No wonder they didn't use much water. There were no water systems in those days. There were wells in some of the squares where the water had to be drawn up in pails, just as it is still in some small towns. The water was often disgustingly dirty

and it was no uncommon thing to find a dead mouse or frog in the pail.

In these old days it was not only that there was a shortage of water, people didn't yet have any idea of cleanliness either. It is only comparatively recently that people have begun to bathe regularly. Three hundred years ago even kings didn't think it necessary to bathe every day.

In the luxurious bedroom of a French king you would have found a huge bed—so big that it was impossible to make it without the help of a special tool called a "bed stick." You would have seen a richly brocaded canopy hung on four gilded pillars, looking like a small temple. There were wonderful carpets, Venetian mirrors, clocks by the best artisans. But you would have hunted in vain for a washstand or even a simple washbasin.

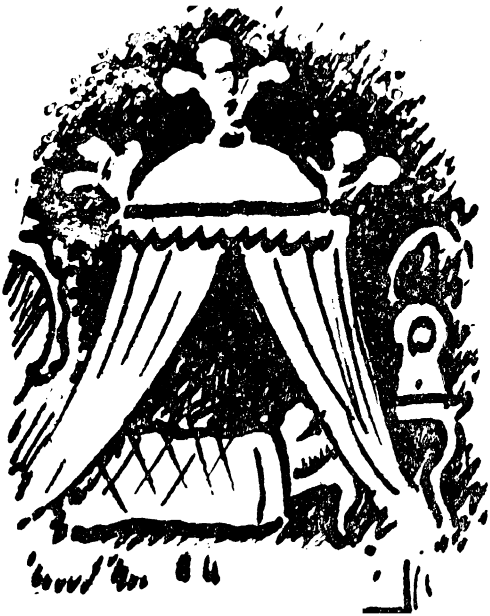
Every morning a damp towel was brought to the king with which to wipe off his face and hands. And everyone thought this ample.

They used very little water for washing clothes, too. In fact, they changed their clothes very rarely. Even quite rich people changed their shirts only once a month, or at the most, twice. Their chief concern was not to have a clean shirt but to have the finest lace cuffs and elaborately embroidered bosoms

on their shirts. At night they took these shirts off with the rest of their clothes and slept naked.

It was only a couple of centuries ago that people began to think it necessary to change their linen oftener.

Pocket handkerchiefs, too, came into use only a comparatively short time ago. At the longest they have not been used for more than two or three centuries. At first only a very few people used handkerchiefs. Even in the highest society there were lots



of people who thought a handkerchief an unnecessary luxury.

The richly brocaded canopies over the beds were put there not so much for ornament as to protect the occupants of the beds from the insects which fell down from the ceiling. In some old palaces we can still see these "bedbug umbrellas." And bedbugs there were in those old palaces by the million. The canopies didn't do much good either, for the bedbugs thrived in the folds of the draperies.

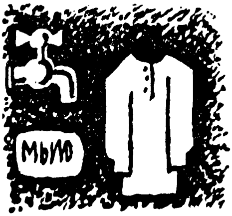
There were no sewage pipes either. People threw

their slops right out into the streets and the dirty water trickled into a gutter in the middle of the street. The stench of this gutter was so bad that passers-by tried to keep as close to the walls of the houses as possible.

No wonder there was much more sickness in those days than now. No one knew then that wherever there is dirt there is bound to be infection. Some-

times it would happen that whole cities would be wiped out by some terrible disease—small-pox or plague. Only five out of every ten children lived to the age of ten. Beggars, disfigured by small-pox or leprosy, thronged the streets.

What is it that has made us healthier and stronger?



Water faucets, soap, and clean shirts.

Why do we Wash with Water?

Why does water wash off dirt? Perhaps it simply carries it off as a stream carries off chips when you throw them in. Well, just try it. Hold your dirty hands under the faucet. Will this make them clean? I'm afraid not. You know that this is not the way people wash. We always rub one hand against the other. Why? To rub or scrape off the dirt.

We do the same thing when we wash clothes. The laundress doesn't simply put the clothes into the water, she rubs them with her hands and sometimes

even scrubs them with a brush. To wash clothes you have to rub the dirt out of them just as we erase or rub out something written on paper with an eraser. And when the dirt is once out it is a simple matter for the water to carry it off.

SOAP BUBBLES ARE PUT TO WORK

But we have forgotten one thing, a thing we always use when we wash clothes.

And that is?—Soap.

If we tried to wash clothes or to wash ourselves without soap we should always be dirty. Soap is the mortal foe of dirt. Take soot, for instance. It is unusually hard to wash off. For soot, minute particles of carbon with sharp uneven edges, gets into the skin and sticks there and you cannot get it loose.

But take a piece of soap and soap your hands well. The soap falls on the soot, hangs on to it and drags it out of all the pores and crevices in the skin.

How does it do this? Why does soap wash?

Well, let's think about it a little. What kind of soap washes best? That which lathers most or that which lathers little or not at all?

That which lathers most. That is, lather is the essential thing.

And what is lather?

Take a look at it. It is all made up of tiny soap bubbles, tiny air-filled globules, whose sides are made of water. It is these bubbles that seize and carry away the soot, if there are enough of them. The particles of carbon stick to the bubbles and it is no trick to wash the bubbles off.

This is precisely what they do in mills where they want to separate a precious metal from the rock in which it is imbedded. They pulverize the ore and put it into strong soap suds. Now soap bubbles are very strong. They pick up the bits of ore and metal and bring them up to the surface. Here a selective process begins. The bits of waste matter cannot stick to the bubbles very long and fall to the bottom of the machine. But the particles of metal don't fall off

and in the end a scum of the precious metal is left on top. This can be easily skimmed off.

So you see soap bubbles are good for something else than to play with. Men are shrewd creatures. They have set even soap bubbles to working for them!

Why do we Drink Water?

That looks like another easy question. So easy that it seems almost silly to ask it. But just try asking it and you will find that not one person in ten knows why we drink water.

You will say: we drink water because we want to.

But why do we want to? Because we can't live without water. And the reason we can't live without water is that we keep using up water all the time so we have to keep replenishing our supply of it.

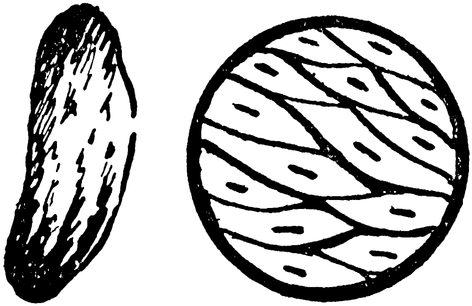
Try breathing on a piece of cold glass. The glass will begin to sweat, there will be little drops of water all over it. Where does this water come from? It comes out of your body.

Or notice how you sweat on a hot day. Where did the sweat come from? It came from the same place, from your own body. Now, if you use up water and lose it, you must replace it from time to time. In the

course of twenty-four hours a man loses as much as twelve glasses of water. Therefore, he must drink or eat an equal amount.

What do you mean by talking about eating water?

Precisely that—we do eat water. In meat, in vegetables, in bread, in everything we eat there is much



more water than solid matter. Meat contains three times as much water as solid matter, and a cucumber is almost all water.

Yes, and your own body has proportionately almost as much water in it as a fresh cucumber. If you weigh 55 pounds this means that you are composed of 48½ pounds of water and 6½ pounds of solid matter. The body of a grown person contains less water in comparison with its weight, but it is still three fourths water.

"Why don't people spill out all over the floor like liquid then?" you ask.

The explanation is this. It does not matter so much what a thing is made of as how it is made.

If we examine a piece of meat or a slice of cucumber under a microscope, we shall see a lot of cells filled with liquid. This liquid doesn't run out of the cells because they are closed on all sides. That's the whole secret. So, you see, the principal ingredient of our bodies is water. It is no wonder, then, that while we can live for a long time without eating it is impossible to live more than a few days without water.

Can Water Blow up a House?

Water seems to be a very harmless thing. But sometimes it can blow up like powder. Like powder? Why, water is twenty times more dangerous than powder if you don't know how to handle it. Once water blew up a house five stories high and caused the death of twenty-three people. This happened in America.

How could that have happened? Well, it was like this: there was a factory in the building and in the basement was a huge furnace with an enormous boiler. This boiler held as much water as a good sized pond. When the furnace was lighted the water boiled

and the steam was carried in pipes to the engines. Once the machinist in charge of the boiler forgot to put in water at the proper time. The water got very low in the boiler. The fire kept right on burning. This made the walls of the boiler very hot. The machinist didn't realize that and went ahead and put water into the red hot boiler.

Now you know what happens when you pour water on hot iron, don't you? It turns into steam instantly. That's just what happened here. The water all turned into steam, too much steam accumulated in the boiler, the boiler wasn't strong enough to withstand the pressure and blew up.

There was a still worse accident once in Germany when twenty boilers blew up all at once. All the buildings in the neighborhood were wrecked and bits of the boilers were carried to a distance of a mile from the scene of the explosion

So you see what a dangerous thing steam is!

Right in your own home, too, several thousand steam boilers explode every day. Only they are very small ones. When you hear the wood crackling in the stove this means that water is blowing it up. There is no such thing as absolutely dry wood. It always contains some water. The heat turns this water into

steam and this bursts the fibers of the wood and makes the crackling sound which you hear.

SOLID WATER

Solid water, that is ice, also explodes sometimes. Steam wrecks buildings but ice blows up whole mountains. This is the way it happens: In the autumn water falls into the crevices of cliffs. In winter this water freezes, turns into ice. Now ice occupies more room than water. Not so very much, only about a tenth more. Under the pressure of the ice which presses equally in every direction, the very strongest rocks burst. That's why water pipes burst, too. Why

they must be kept warm in winter by wrapping them up in something like felt.

Why can't we Skate on the Floor?

One boy, when I asked him why he couldn't skate on the floor, said: "Because ice is very hard and slippery. The floor is not so hard and it is not slippery."

But there are floors made of stone. They are hard and slippery. But you can't skate on a stone floor either.

When we skate on ice the pressure of the skates melts the ice. Between the skates and the ice a layer of water is formed. If it weren't for this layer of water it would be just as hard to skate on ice as on the floor. Water, just like oil in a machine, reduces the friction between the skate and the ice.

The movement of glaciers down mountain sides is due to the same cause. Under the weight of the ice the lower layer melts and the ice river slips down the mountain slope just as your skates glide along over the ice.

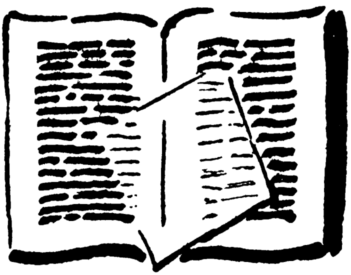
Is Water ever Opaque, or Iron Transparent?

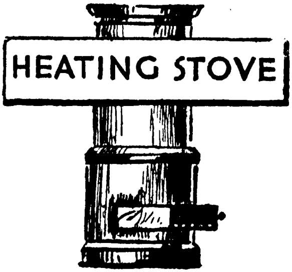
You will all say that water is transparent. But the fact is that it is only the top layer that is transparent. At the bottom of the ocean it is pitch dark because

the sun's rays cannot penetrate the whole mass of the water.

And it isn't water only that is transparent. Every substance is transparent if you take a thin enough layer of it. Take a piece of clear, transparent glass, for instance, and look at the edge of it. It won't look either clear or transparent to you.

Not long ago a certain scientist made a sheet of iron only a hundred thousandth of a millimeter thick. This sheet of iron was as transparent as a sheet of glass and almost as colorless. If you held it over the page of a book you could read the finest print through it without the least difficulty. Scientists have made similar sheets of gold and of other metals.





STATION TWO
THE STOVE

When did People first find out how to Start a Fire?

How cheerily the fire crackles in the stove on a winter evening! When you look into it you can easily imagine you see a lot of wonderful things—burning cities, besieged forts. The crackling of the logs seems to be the rattle of gunfire and the tongues of flame are the soldiers running along the walls of the fortresses.

In olden times people thought that tiny, fiery lizards lived in the fire, spirits of the fire. And there

were some who thought that fire was a god and built temples in its honor. For centuries lamps dedicated to the god of fire were kept constantly burning in these temples, never allowed to go out for an instant.

The custom of keeping a perpetual fire is one of the most ancient customs in the world. Thousands of years ago people didn't know how to start a fire. They didn't start a fire, they found one. Just as we now find precious stones. No wonder that fire was guarded as a precious treasure, for if it went out there was no place where they could get any more. And they didn't know how to start it.

Lightning would strike a tree and set it on fire. People would look with terror at the fiery beast which was devouring the tree, cracking off the branches and licking up the bark with its tongue. They were afraid to get too near it, but they didn't want to go away either—it was so nice and warm round a burning tree on a cold night!

But primitive man was a bold creature. He had to fight great hairy mammoths and powerful cave bears. So finally some brave soul got up his courage to go up close to the fire when it was dying down. We don't know who was the first person who had the

courage to seize a burning branch and carry his wonderful prize home with him. Very likely it was not just one man who did it, but several of them in different parts of the world. At any rate they were surely bold, adventurous souls who first caught and tamed fire, just as we tame a wild animal.

The achievement of Edison in inventing the first electric lamp was nothing in comparison with the exploit of these awkward, long-armed men, clad in the skins of wild beasts. If it were not for fire we should even now be very little different from the orang-outang or the gorilla.

So the caves and mud huts of these primitive men were brightened by firelight. But it was many thousands of years yet before they learned how to start a fire.

Once man learned how to start a fire he need not fear losing it. If wind or rain put his fire out he could always start a new one. But they kept a perpetual fire burning in little lamps in their temples for a long time yet, in remembrance of the time when they

didn't know how to start a fire, when it was still a rare and precious treasure.

It may sound strange, but it is nevertheless true, that we have kept to this day the very oldest method of starting a fire. Primitive people rubbed one piece of wood on another to start a fire. We do the same thing—rub a match on a box.

But there is a very great difference. It takes only an instant to light a match. It took at least five minutes or more to set even the driest piece of wood on fire. And besides you had to know how to do it. Anyone can light a match. But just try to make a fire in the primitive way! I very much doubt whether you would get any result.

Why do Matches Light?

Primitive man didn't have any such tools as we have. He had neither saw nor plane. He sawed and planed with a sharp stone or piece of bone. It was no easy thing to work with such a tool. He had to rub and scrape so long that the wood finally got hot and even sometimes burst into flame. This was probably the way he found out that fire could be got by friction.

Wood has to get very hot before it will burst into

flame. This means that the two pieces of wood have to be rubbed together for a long, long time.

It's very different with a match. The match head is made of a material which catches fire when it is heated ever so little. All you have to do is to touch a match to a piece of hot iron, the hot stove door for instance, and it will burst into flame. Touch the door with the other end of the match and nothing happens. That is the reason you don't have to rub a match on the box for five minutes. All you have to do is to scratch it and it flames up at once.

When were Matches Invented?

Matches were invented only a short time ago. In 1933 we celebrate the hundredth anniversary of the first match factory. Before this fire was started in some other way. Instead of a match box, people who lived a hundred years ago used to carry about in their pockets a little box with three odd looking things in it: a bit of metal, a little stone, and a small piece of something which looked like a sponge.

If you had asked them what these things were, they would have said that the metal was the "steel," the bit of stone the "flint," and the piece of sponge the "tinder."

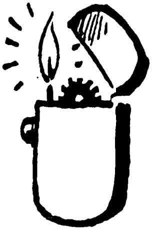
What a lot of things to take the place of one match!

How did they start a fire?

Take a look at this fat fellow in a bathrobe, with a long pipe in his mouth. He is holding a steel in one

hand, the flint and tinder in the other. He strikes the steel on the flint. No result! Again. Still no result. He

tries it again. This time there is a spark from the flint but the tinder doesn't catch. Finally at the fourth or fifth attempt the tinder catches.



This is really the same principle as our present day cigarette lighters. In the lighter there is also a bit of

flint and a piece of steel, the little wheel. The little wick soaked in gasoline is the tinder.

So you see that it was no easy matter to start a fire.

Yet when European explorers wanted to teach the Eskimos in Greenland the modern way of doing it, the Eskimos would have none of it. They thought their own old way better, that is, to start a flame by friction, twirling a stick on a dry piece of wood by means of a leather thong.

Even the Europeans were not so ready to give up their steel and flint for something better. From time to time there have appeared on the market all kinds of complicated devices for "chemical ignition." There were matches which ignited when touched to sulphuric acid, matches with glass heads which had to be squeezed with a pair of pincers to make them light. And there was one elaborate contraption made entirely of glass. But they were all inconvenient and expensive.

This sort of thing went on until the invention of phosphorus matches. Phosphorus is a substance which ignites at the very lowest heat, as low as 140° F. You would suppose that there couldn't be a better material for matches. But phosphorus matches are nowhere nearly so good as the ones we make at the present time. They were very poisonous. And the worst thing about them was that they ignited too easily. All that was necessary was the lightest scratch on the wall or even on a piece of soft leather. And

when the match ignited there was an explosion and the head flew off in different directions like a small sized bomb. Also after the match had burned it left a bad memory behind it in the form of a disagreeable, sulphurous gas. For there was sulphur in these match heads as well as phosphorus and it turned into sulphuric dioxide when it burned.

Sixty years ago "safety" or "Swedish" matches finally put in their appearance. This is the kind we still use. There is no phosphorus at all in these matches. Other combustible materials are used instead. There is no sulphur either. They are safe and non-poisonous.

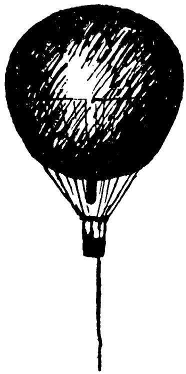
Why Doesn't Water Burn?

Some things burn when they are very hot. Other things take fire even when they are but slightly heated. But there are some things which never burn at all. Water, for instance, doesn't burn. Do you want to know why?

Well, it is for the same reason that ashes don't burn. Because water is made by burning. What is it that has to be burned in order to produce water? Hydrogen gas—the same kind of gas that is used in balloons.

In America they are now using another kind of

gas in balloons—helium. Helium doesn't burn, so balloons filled with it are less dangerous.



What Becomes of the Wood which is Burned in the Stove?

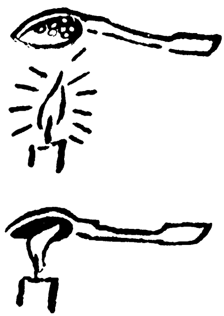
You brought in a heavy load of wood from the woodshed and threw it down on the floor with a great racket. They were big fine logs. The room was filled with their spicy fragrance. You put them into the stove and started the fire. Now half an hour later look in. There's not a thing left of your armful of wood! Only a damp spot on the floor left by the melting snow and a handful or two of ashes in the stove.

What has become of the load of wood? It has burned up. But what do you mean by "burned up"?

We must look into this. A candle disappears, too, when it burns. Do they really disappear, or only seem to?

Let's try an experiment: take a spoon and a candle. Hold the spoon over the candle flame. It gets black and is covered with drops of water. Where does the water come from? Evidently from the candle flame. There is no other place it could have come from. Now, wipe the spoon off and hold it in the flame: it is covered with soot, tiny particles of carbon. Where did the carbon come from? From the candle flame again.

Why was it that we didn't see the water and the carbon before?



For the same reason that you can't see the beams and nails in your house. You only see the beams and nails and bricks when the house burns up. The same thing is true here: the water and coal are only visible when we make a small conflagration—light the candle.

Very well. When the candle burns we get water and carbon. But what becomes of them? The water goes off in the form of steam. This is the steam which

condensed on the spoon when we held it over the flame. But what becomes of the carbon? When the candle smokes the carbon goes off in the form of soot—tiny particles of carbon—and settles on the ceiling, walls, and furniture of the room.

But if the candle is burning well there is no soot, for the carbon is all burned up. Burned up? What do we mean by that?

Now we have to begin at the beginning again. What becomes of carbon when it burns up? One of two things: either it is lost, disappears entirely, or it is turned into some other substance which we simply don't see.

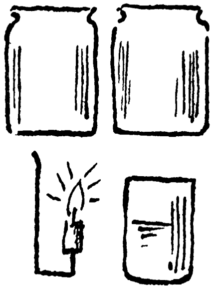
Let's try to catch this ghost.

To do this we must have the things shown in the picture, that is, two jam jars, a candle end fastened to a wire so it can be let down into the jar, and a glass of lime water. To prepare this water mix a little quicklime with water and filter it through a piece of blotting paper. If the solution obtained is still cloudy it must be filtered a second time so that it will be perfectly clear.

Now light the candle and let it down very carefully into the jar. It will burn down and finally go out. Take it out, light it and let it down into the jar again. This time it will go out immediately as if you

had immersed it in water. This shows that there must be something in the jar now which puts the candle out. What can it be? The jar seems to be perfectly empty.

Now I'll tell you what we'll do. Pour the lime water into the jar. The water begins to grow cloudy



and finally becomes entirely white. But if we pour the lime water into the other jar it remains clear. This shows that in the jar where the candle was burned there is some invisible gas which turns lime water cloudy. Scientists have named this gas carbon dioxide. They have discovered that carbon dioxide is produced whenever carbon is burned. Now we can answer the question as to what became of the candle flame: it turned first into carbon and water, then the carbon was burned up and turned into carbon dioxide.

The same thing happens when wood is burned. The wood also is turned into carbon and water. The carbon burns up—not all of it however. Some of the unburned carbon is always left in the stove. But the carbon which has been burned up, that is carbon dioxide, goes off up the chimney with the water

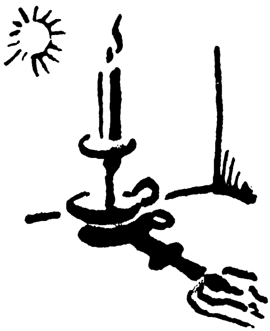
vapor. The white smoke which comes from chimneys in winter is this steam, condensed by the cold into drops of water. If the smoke is black this means that the stove is sooting or smoking, that there is a lot of unburned carbon or soot in the smoke.

Why does the Stove make such a Noise When the Fire is Lighted?

As soon as you light the fire in the stove on a winter's day you have music in the room. The stove hums and sings like the big bass trumpet in the orchestra. The stove doors tinkle and jingle like brass

cymbals. Where does all this humming and jingling come from?

You have to blow on a trumpet to make a sound on it. But who is blowing on the stove? This is what is happening: When we start a fire in the stove the air



in it is heated. Now, hot air is lighter than cold. It rises up and the cold air in the room rushes in to take its place. There is a draft, a current of air going through the stove from bottom to top.

You can easily test this. Put some bits of paper on a post card or a playing card, near the edges. Hold the post card close to a hole in the stove door. The bits of paper will fly into the stove.

What carried them in?

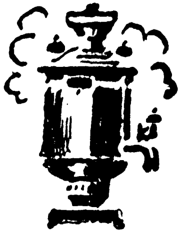
A current of air flowing from the room into the stove. It carried the bits of paper along with it just

as a river carries along the chips you throw into the water. That is, no one is blowing into the stove. The air is going in of itself.

But is it really true that when air is heated it rises?

You can see this with your own eyes. Put a lighted candle or lamp in the window on a sunny day. You will see the shadow of the flame on the window sill and under it a moving shadow of the air which is rising upwards. That is why a flame always goes upward—the hot air is rising and carries the flame along with it.

Now do you see why they always make holes in a stove door? To let the air in. But why is air needed? So that the wood will burn. Without air, in an airtight stove, for instance, the wood would not burn. The better the draft the better the wood burns. You have undoubtedly noticed yourself that when there is a strong draft the wood burns well and when the draft is poor it hardly burns at all.



There are holes in the samovar for air, too. See if you can find them!

Why does Water put a Fire out?

If you immerse a candle in water it will go out. But why?

Because the candle has to have air, not water, in order to burn. That's precisely why water puts the fire out; because it doesn't allow air to get to it. A fire can be put out in other ways, too—by covering it with a blanket or throwing sand on it. The blanket or the sand prevents the air from reaching the fire and it goes out.

Why do we Blow on a Match to put it out?

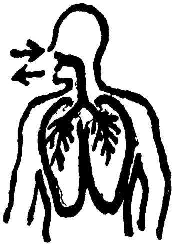
We never pour water on a lighted match or candle when we want to put them out. You can put a small fire out by merely blowing on it. But why does this make the fire go out?

To light a match you have to heat it: scratch it on the box or touch it to something hot.

What must we do to put it out? Make it cold again, cool it off. And how do we cool it off? By blowing on it—that's all. That is, we blow on a match to cool it, and this makes it go out.

A Riddle about a Stove

Guess this riddle: A fire is started in a stove, but there is no fire. Air goes in and smoke comes out. What is it?

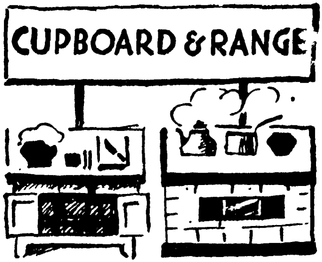


It is a human being.

You see, when we breathe we take in air, but we breathe out water and carbon dioxide. Just like a stove.

You can easily prove this. Breathe on a spoon, it will sweat. There's your water. Now blow through a straw into lime water. The water becomes cloudy. There's your carbon dioxide.

Your mouth serves as both door and chimney to this stove. Our food is the fuel for our stove. That's why the body is always warm.



STATION THREE
THE KITCHEN CUPBOARD AND RANGE

The Kitchen Laboratory

THE dry pine sticks crackle as they burn. The cheery flame, like a country fiddler, sets everything on the kitchen stove a-dancing. The blue enamel teakettle throws its lid into the air, like a cap, and catches it on the fly. The iron frying pan sputters and shakes with joy. Even the big copper saucepan forgets its dignity, giggles like a simpleton and spills boiling water all over its neighbor, the iron pot. You call it a kitchen—but I call it a chemical laboratory.

Here, just as in a chemical laboratory, one thing is changed into another totally unlike it. The most mysterious things go on in these saucepans, pots, and kettles. A little ball of dough in the mixing bowl

suddenly came to life and began to grow until it was higher than the edge of the bowl. A bit of meat put into a saucepan was so changed at the end of an hour or so that you would never have recognized it. It was all split up into fibers barely holding together, and had changed in color from red to gray. Potatoes, which a short time ago were firm and solid, got soft and mealy.

It was no learned chemist who performed all these miracles. It was just an ordinary housewife, with her sleeves rolled up and an apron tied round her waist. This woman bustling round the stove hasn't the least idea what is going on in her pots and kettles. Does she know, for instance, what happens when she boils potatoes?

What is a Potato?

What is a potato?

Why everybody knows what a potato is, you will say.

No, you're wrong. Not everybody. Take yourself, for instance, do you know what a potato is made of? If you don't, try this experiment: Grate a potato, mix it with water in a jar, strain it through a cloth and let the liquid stand. A layer of some white substance will settle to the bottom of the jar. Pour off the water, spread this sediment out on a piece of blotting paper and let it dry. You will get a white powder.

What is it?

It is starch. Cooks call it potato flour. There's a great deal of starch in potatoes. Why is it then that ordinarily we can't see it? It is because the grains of starch are stored away out of sight in the potato, as if in a storehouse, put away in tiny bins, or cells.

Why don't we Eat Potatoes Raw?

Because it isn't so easy to get at the starch. We'd have to grate the potatoes up on a grater. And there isn't any grater in our stomachs. The stomach isn't able to do this work. That's why no one eats raw

potatoes. When we boil the potatoes the walls of the cells are broken down by the heat and the water gets into the starch grains. This makes them swell and get soft.

A potato which has been boiled in water seems dry because these grains have absorbed all the water. That's why the potato comes out of the water dry.

Why is it that a Baked Potato has a Crust and a Boiled Potato Has None?

When we bake a potato we heat it very hot, much hotter than when we boil it. The intense heat turns the starch on the outside of the potato into dextrine, a glue, which glues the other starch grains together into a reddish crust. You have probably used glue made of dextrine without knowing what it was made of. This is the kind of glue often used on labels.

Why are Starched Clothes Stiff?

When the clothes are pressed with a hot iron the heat turns the starch into dextrine. A stiff crust is formed like that on the baked potato.

That's why your starched collar is so stiff that it cuts your neck.

Why does Bread have a Crust?

Flour, not potato flour but the ordinary kind of flour, contains starch too. So when bread is baked a crust is formed on it in the same way.

Is it really true that there is starch in flour? Maybe I am deceiving you and there isn't any. You'd better prove it for yourselves.

Tie up a little piece of dough in a cloth and wet it in a cup of water, squeezing it all the time. The water will get as white as milk and you will find the same kind of white sediment at the bottom of the cup that you got from the potato. That is, I was telling the truth when I said that there was starch in flour.

Why does Bread Harden?

Hold a bag of flour under the water faucet until all the starch washes out. You'll have a little sticky

elastic ball left in the bag. This is gluten. There is one sign by which you can easily recognize gluten. Set it aside and leave it alone for two or three hours and it will become hard and brittle like glass. That's the reason bread gets hard. The gluten in it has become hard and brittle.

Why does Dough Rise when you put Yeast in it?

For the same reason that a rubber ball expands when you blow air into it. Only in the dough, in place of rubber we have the equally elastic gluten, and in place of air, carbon dioxide.

Next time they are making the dough into loaves at your house take a piece and put it into a jar and cover the jar closely. Next day open the jar very carefully and lower a lighted match into it.

The match will go out instantly. Why? Because there is an accumulation of carbon dioxide in the jar. When yeast is put into dough a lot of bubbles of carbon dioxide are formed. These bubbles make the bread rise up like a mountain. Where does the carbon dioxide come from? The yeast makes it out of the dough. Every yeast cake is a little chemical factory for producing carbon dioxide.

Why is Bread full of Holes?

When the dough is put into the stove the gluten is dried by the heat and becomes brittle. The bag which for so long had kept the carbon dioxide imprisoned is burst and the gas is liberated.

That is why bread is full of air holes and is crumbly. Every air hole in the bread is a trace left by the bubbles of carbon dioxide.

THE CHEMICAL HISTORY OF A LOAF OF BREAD

Now I am going to tell you the history of a loaf of bread from the very beginning. You will find it all very familiar and simple.

A cook wanted to make a loaf of bread. So she poured some water into a big mixing bowl and put in yeast and salt, sifted in flour and, rolling her sleeves up above her elbows, began to mix it. The

gluten stuck the light fluffy particles of flour together into a big soft ball. The cook then covered the bowl and set it in a warm place.

Then the work began. The yeast fell on the dough and set about its special job of making carbon dioxide. If there were no gluten in the dough this carbon dioxide would have escaped immediately. But the gluten is flexible and elastic and does not permit the bubbles of gas to get out. No matter how hard it tries to make its escape, no matter how it pushes against the walls of its prison, it cannot break through the elastic gluten bag.

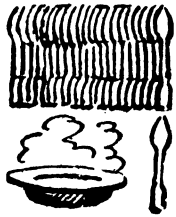
The ball of dough comes to life. It begins to move, to rise higher and higher as if it wanted to get out of the bowl. Next the dough is put into the oven. There it undergoes a number of changes. On the outside of the loaf where the heat is greatest, the starch is turned into dextrine. This gives it a hard crust. Inside the loaf the starch swells, just as it does in a potato, and becomes soft. The gluten dries and bursts and lets the carbon dioxide escape. And finally a delightful aroma of freshly baked bread spreads through the room.

Why does Beer Bubble and Foam?

How is beer made?

Freshly sprouted grains of barley or wheat are put into water and yeast is added. The yeast sets to work and turns the grains into carbon dioxide.

The bubbles which rise in the beer and make it foam are bubbles of carbon dioxide gas.



What is Soup?

Many people think that bouillon is a very nourishing dish. But there is really very little nourishment in it, not much more than in pure water. In a plate of bouillon containing twenty tablespoons of water there is only one tablespoon of other substances.

If you boil bouillon down on the stove until all the water evaporates there will be almost nothing left in the bottom of the saucepan. If you should take a plate of soup to a laboratory and have it analyzed you would find that besides the nineteen tablespoons of water, it contained one fourth spoon-

ful of fat, one fourth spoonful of glue—yes, ordinary furniture glue—and a little salt (not only common salt but also other salts). The rest is merely "taste matters," that is that part of the meat which gives it its taste. When the meat is boiled these taste matters are dissolved in the water.

But it isn't soup only that has so much water in it. Nearly everything we eat contains much more water than you would think at first glance. Vegetables contain so much water that they become as light as down when they are dried. And every pound of meat contains three fourths of a pound of water. There is just as much water in potatoes, too.

Why do we Eat Meat?

We've finished our soup. Now we come to our meat course. If you should have an analysis made of meat you would find that it contains, just as the soup did, water, taste matters, and salts. But besides this it contains one thing of which there is very little in soup—albumen.

When meat is boiled part of the albumen is boiled out and floats about in flakes in the water. Cooks skim off this foamy scum so that the soup will look nicer. But they shouldn't do it. For the albumen of the meat is very nourishing. We cannot live without

albumen because our own flesh, just like beef or veal, is composed almost entirely of water and albumen. If we eat food in which there is a great deal of fat, sugar, and starch but no albumen at all, we shall sooner or later die from a lack of the materials necessary to the repair of our bodies.

There are two kinds of food: fats, sugars, and starches are heat-producing foods which warm our bodies and keep the whole machine going. But albumen is the most important building material of which we build our bodies. As "when there is no wood we have to burn up the chairs," so when there are no fats, sugars, or starches people burn up the albumen. That is, albumen can serve as a fuel as well as a building material. That is why human beings absolutely must have albumen.

What Glues Meat Together?

Boiled meat falls apart into fibers. In raw meat these fibers are glued together, and very tightly, too. To get this glue from the meat you must boil it for a long, long time, until it falls to pieces. The material which glued the fibers together will then be dissolved in the water. If you let this solution cool, it will turn to a jelly and if you then dry this jelly, what do you think you will have? Ordinary furniture glue.

That is, meat is glued together with furniture glue, just as chairs and tables are.

There, we have finished our dinner. We had soup and meat, bread and potatoes. Now we know what we have eaten and what good it did us.

DINNER IN A BOTTLE

The very best food in the world is that which animals give their young—milk. Milk makes muscles,

skin, bones, nails, and teeth. Milk turns a helpless little lion cub into a mighty beast who makes the very mountains tremble when he roars. The huge whale is also fed on milk; so is the tiny guinea pig.

Milk contains everything a child needs—water, fat, sugar, albumen, and salts. The fat floats about in the milk in the form of tiny little droplets. As fat is lighter than water it gradually comes to the top and forms a layer of cream. If this cream is churned it turns to butter. The little globules of fat are gathered

together by the churning and separate out from the water.

You can make some butter if you will put some cream in a bottle, close it up tightly, and shake it for a long time.

Why does Milk Sour?

When milk stands for a day or two it turns sour. But you can make it sour and form a curd in two seconds instead of two days. Just add a little vinegar to the milk. The curd will separate out at once.

Curd is casein, the albumen of milk. It is in a state of solution in the milk just as sugar is in water. As soon as an acid is added to the milk this casein separates out, taking the fat with it.

But, you say, no one ever puts acid into milk. What is it then that makes it sour?

Certain germs, something like yeast germs, which are always present in the air, are to blame for it. When they fall into the milk they begin their work —turning milk sugar into lactic acid. And this acid makes the milk curdle. To keep milk from souring it must be boiled. This kills the germs. Sometimes the milk curdles while it is being boiled. This is because the germs in it have already done their work and made the acid.

Where do the Holes in Cheese come from?

If curdled milk is kept for a long time in a cellar, the work of the germs goes on and finally the curd turns into cheese. The holes in the cheese are the same as the holes in bread. They are made by carbon dioxide. Where does it come from? The germs make it.

Cheese keeps so long because it is covered on the outside with a crust which does not let it dry up and protects it from harmful germs.

They say that the Swiss have a custom of making a big cheese on the day a child is born, putting his name and the date on it. At every birthday celebration this cheese is put on the table. It accompanies its possessor from the cradle to the grave, and at his death he bequeathes it to his children.

Swiss newspapers had a story about a cheese a hundred and twenty years old. This "great grandfather" cheese was cut up and eaten quite recently. And it was said to be delicious.

What did People Eat in Olden Times?

There was a time when people didn't know how to cultivate the soil and lived almost exclusively on meat. They ate not only wild animals and birds

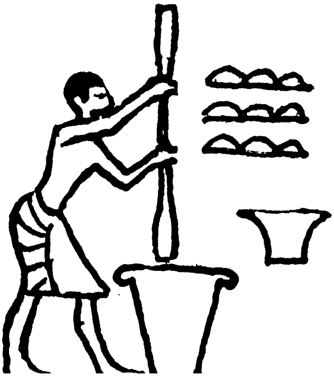
killed in hunting but also prisoners taken in war. They say that the warriors of a certain African tribe rush to battle with the cry of: "Meat! Meat!" Fancy the terror of the defeated and retreating foe when they hear this cry!

One of the first North American colonists tells of the surprise of the Indian hunters when they first saw the grain fields of the Whites. The chief of one of these tribes told his fellow warriors:

"The Whites are more powerful than we because they eat grain and we eat meat. You see, we can't find meat all the time. And it takes meat several years to grow. But every one of these magic grains the white people throw into the ground comes back to them with hundreds of others in a few months' time.

"The meat which we eat has four legs to run away from us on, while we have only two to run after them. The grain stays in one place and grows where it is thrown.

"In winter we freeze in our woods, hunting all day long. The Whites sit comfortably at home. I warn you all that before the trees growing beside our wigwams fall, the grain eaters will have exterminated the meat eaters."



It is difficult to say when the first grain was sown by the hand of man. In ancient Egyptian pyramids we find pictures of people grinding grain between stones.

The ancestor of our bread was not very much like the bread of today. It was a paste made of crushed grain, mixed with water. This would sometimes dry up and pieces of it were used by the people of those

days for bread. Even now in the Orient they make corn cakes of unfermented, unleavened dough.

Now, this paste sometimes soured and this made it more crumbly and soft. Finally someone had the idea of mixing this sour paste with the freshly ground grain—and so bread was invented.

What made the paste sour?

It was because yeast germs fell into it from the air. These and many other kinds of germs are always to be found floating about in the air. Some bakers still use a piece of fermented dough instead of yeast to start the fresh dough.

Many years passed before people found out how to cultivate the soil properly and how to make good bread. As late as two hundred years ago fairly well-to-do people still ate bread that no one would think of eating today. And even rich people never had potatoes.

The potato appeared in Europe very recently. At the time of the French Revolution the potato was still a novelty. A French queen used to wear a bouquet of potato blossoms. And boiled potatoes weren't to be found every day even on royal tables.

The potato is a native of distant lands—Peru and

Chile. We know the exact year when the first potatoes were brought to Europe from America: they were brought from the Spanish possessions with a load of silver and gold in the year 1534. In the course of the next fifty years the potato spread from Spain into other European countries, first to England and Austria and later to Germany and France.

At first people were very suspicious of the potato as a food, especially the older ones who weren't used to them. They say the children took to them at once and liked them much better than chestnuts.

The potato was very happy in its new country. It was not many years before this imported foreign novelty had become the staple food of the poor instead of a delicacy on the tables of kings.

What did People Drink in Olden Times?

Rich people drank wine and mead. The poor drank water. But neither the rich nor the poor had ever heard of tea or coffee.

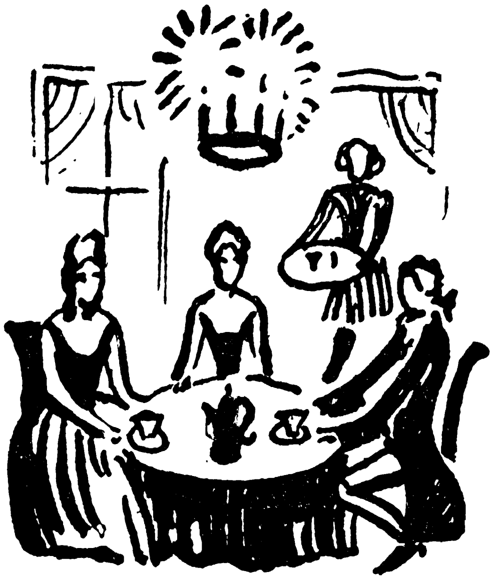
It was only three hundred years ago that Europeans first heard about a wonderful drink the Chinese and Japanese had. It was said that this drink prolonged life. It was not until the year 1610 that tea was first introduced into Europe. In Russia it

was a hundred years after this that people began to drink tea. Dutch merchants were the first to bring tea to Europe from the far away island of Java. As usual these merchants began to advertise the merits of their wares. They called tea a "divine herb," ad-

vised people to drink forty or fifty cups a day, at all times of day and night. One Dutch doctor used to prescribe it in place of all other medicines for every kind of disease.

But tea is really not an herb. It is made of the leaves of the tea tree. And it is not in any sense a medicine. Strong tea is very bad for the health. In spite of all the efforts of the merchants only the rich took to tea drinking at first as it was very expensive.

Shortly after tea, coffee made its appearance. French merchants had for a long time been bringing back stories from Turkey and Egypt about a wonderful tree that grew there. How the Turks made a



drink from this tree which they called "kaova" or "kofa" and drank it in their taverns in place of wine. They said this drink drove away worry, aided digestion, and made men strong and healthy.

Soon coffee appeared at the dinner parties of the

French king. The dukes followed the example of the king, the counts and viscounts that of the dukes, and all the titled and untitled folk, merchants, doctors, and lawyers, followed the example of the people of the court. Coffee houses were opened and people sat in them all day long. For in those days whatever was done at court became the style at once.

Coffee had its enemies too. Some people thought Catholics ought not to drink this Turkish beverage. Others said that Minister Colbert had burned his stomach with it, that coffee shortened one's life, caused colic and other stomach troubles. One princess said that not for anything in the world would she drink this "soot and water," as she called coffee, that she preferred "good old beer to all these foreign drinks."

Chocolate had a still worse reception. People said it was fit only to feed to pigs; that it burned up the blood and would even kill a man.

It is true that the chocolate which the famous explorer Cortez brought back with him from Mexico was not at all like our chocolate of today. The Mexicans made chocolate from a mixture of cocoa, maize, and pepper and didn't put any sugar in it at all. It was only later that people learned to make chocolate

as we do, that is, to crush the cocoa beans and grind them up with sugar, vanilla, and other flavorings.

Who was right in these discussions about tea, coffee, and chocolate?

Tea and coffee contain very little nourishment and besides they contain materials which are harmful to the heart and nerves. Chocolate and cocoa, especially chocolate, are quite the opposite. They contain fats and albumens. That is why travelers going to Polar regions always take along a big supply of chocolate.

Cocoa is less nourishing than chocolate. In preparing it the cocoa beans are first crushed, then heated, and the fat is pressed out of the powder. So there is less fat in cocoa than in chocolate.

What Tools did People Use to Eat with?

There was no lack of fine utensils on the tables of the rich. Silver and gold plate aplenty. They had everything you could think of. But there was one thing they didn't have—forks—common, everyday forks.

They ate with their fingers and weren't in the least ashamed to put their five fingers right into the

common dish. Even knives weren't plentiful, two or three at most on the whole table. One had to borrow a knife occasionally from one's neighbor.

There were no plates either. Big slices of bread served as plates. After dinner they used to throw these gravy-soaked "plates" to beggars or dogs. It was only three hundred years ago that plates and forks came into use. And then not in every home, only in palaces.

If you want to know how rich people used to eat in ancient times, come with me to a medieval castle at dinner time. We climb up a high stone stairway and enter a spacious dark hall, with high vaulted ceiling, dimly lighted with torches. The windows are all closed with shutters, although it is still bright daylight outside. In winter time they had to do this to keep the heat in, for glass had not yet been invented.

Although this is the dining-room there is no dining table in sight. The table is brought in, or rather, made, just before dinner is served.

There come the servants in sleeveless green homespun garments, wearing long yellow stockings and red boots with pointed toes. In the twinkling of an eye they set up trestles and lay planks on them. When

the table is made they cover it with a white table cloth embroidered with reindeer, dogs, and huntsmen with horns in their mouths.

They place a salt cellar on the table, put plates of bread round, and lay out a couple of knives. All they have to do now is to move the benches up to the table and summon the guests to dinner.

The gentlemen come in, a noisy crowd. The master of the castle, his sons, and the guests—neighboring landlords. They have just come in from hunting wild boars. They are all tall, bearded men with rosy cheeks.

Two pet dogs of the host come in with them, fierce beasts, ready at the slightest sign to tear a man to pieces. Last of all comes the wife of the knight, who has been busy with the overseeing of all these preparations.

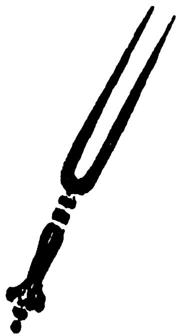
The company sits down at the table. They are all as hungry as wolves. The cup bearer, that is the servant who serves the meat, brings in from the kitchen outside the castle a huge dish of smoking bear meat. He carves the meat and offers it on the point of his knife to the assembled guests. The meat is highly peppered and stimulates the palate. A quarter of a bear disappears in a quarter of an hour. This is followed by the flank of a wild boar with the same hot sauce, a reindeer roasted whole, swans, peacocks, and all kinds of fish.

A heap of animal and fish bones piles up on the table cloth at each plate. There is a lively time under the table, too, where the dogs are growling at each other as they gnaw the bones thrown to them by the guests.

They eat long and heartily. Eating was the chief means of entertainment in this bear's den. The servants can hardly bring on the courses fast enough. Pies and cakes, apples and nuts. They drink up nearly a barrel of wine and mead with the dinner. It is no wonder that at the end of the feast some of the guests are rolling on the floor, their long, steady snoring echoing through the hall above the din of raucous shouting and laughter and the noisy barking of the dogs.

THE FIRST FORK COMES TO ENGLAND

In 1608 an Englishman named Thomas Coryate made a journey to Italy. He kept a diary during his trip where he wrote down everything which especially attracted his attention. He has wonderful descriptions of Venetian palaces standing in the water, of the beauty of the marble temples of ancient Rome, and the awful grandeur of Vesuvius. But there was one thing which astonished Coryate more even than Vesuvius or the palaces of Venice.



On one of the pages of his diary we find the following note:

"When the Italians eat meat they use little pitchforks made of iron or steel, or sometimes of silver. It is considered very bad manners to eat with the fingers because, they say, people do not always have clean hands."

Before he returned home Coryate ordered some of these "pitchforks" for himself. The fork he bought didn't look very much like ours. It had only two prongs and the tiny handle, finished with a knob at the end, was scarcely longer than the prongs. It

looked much more like a tuning fork than a table fork.

When he got home Coryate decid d to show off his purchase to his friends and acquaintances. He gave a dinner party and when the meat was served he took out his fork and began to eat in the Italian fashion.

All eyes were on him. When he explained what kind of thing it was he was using they all wanted to have a closer look at the Italian eating tool. The fork went the rounds of the table. The ladies admired its ornate decorations and the men were struck with the ingenuity of the Italians, but all agreed that the Italians were great fools because the fork was very inconvenient.

Thomas Coryate argued with them and explained to them that it was not nice to eat meat with one's fingers because people didn't always have clean hands. Everyone was indignant at this. Did Mr. Coryate think that people in England didn't wash their hands before eating? And weren't the ten fingers given to us by nature enough for us? Must we add two artificial ones? Let him just try to show how easy it was to manage this clumsy pitchfork!

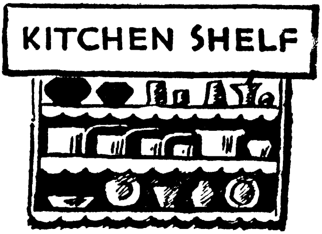
Coryate wanted to display his skill. But the first piece of meat he picked up off his plate slipped off

the fork to the table cloth. They almost never stopped laughing and joking about it, until the poor traveler had to put his fork back into his pocket.

Fifty years passed before forks came into style in England. There are all kinds of traditions and legends about how people found out how to start a fire, about who was the first blacksmith and so forth. And there is a story, too, about why people began to use forks. They say that

forks came into use when people began to wear wide lace-trimmed collars. These collars hindered them when they ate. They held the chin up in the air and kept one from bending his head. It was as if the head were set on a big round plate. With such a collar it is manifestly more convenient to eat with a fork than with the fingers.

This is probably a myth. Forks came into use at the same time that people began to change their linen oftener and to wash themselves. That is, when people became more cleanly.



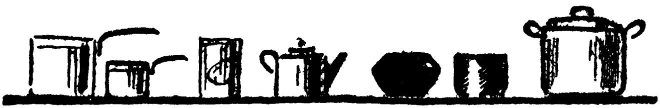
STATION FOUR
THE KITCHEN SHELF

Seven Things—Seven Riddles

IF YOU are not tired traveling round the room from sink to stove and from stove to cupboard, let's go on now to our fourth stopping place, the kitchen shelf. And let us do what all travelers do, look over the place and write down in our diary everything we see: Two copper saucepans. A cookie tin. A tin teakettle. An earthenware pot. An iron pot. A big white soup kettle.

There, that's everything there is on the shelf. Seven things—seven riddles. Riddles, you say? How absurd to call saucepans and clay pots riddles!

What? They're not riddles? Of course they are. Take the two saucepans. You say they're both copper. Then why are they of different colors, one red and one yellow? And why are they both white on the inside? Maybe you think copper comes in three different colors, white, red, and yellow?



Or tell me can a little saucepan be heavier than a big one, when the sides and bottom are of exactly the same thickness?

You will say it can't. But just lift up this big white soup kettle. It is three times as big as the copper one and weighs only half as much. Why? Because it is made of a very light metal—aluminum.

The clay pot looks very crude and homely compared with the soup kettle. But they are very closely related just the same. How can that be, you say?

Or take the teakettle and the cookie tin. They are both made of tin. But what is tin? What is the difference between iron and tin? And finally the iron pot. Do you think you can break it? You wouldn't think so, cast iron isn't glass. But as a matter of fact

you can break it very easily. All you have to do is to give it a good blow with a hammer.

So you see every single thing is a riddle.

Why Things are Made of Different Materials

Each one of these seven articles is made of a different material. Why not make them all of the same thing? Sometimes you can. For instance, the kettle can be made of either cast iron or copper. There are copper teakettles and tin teakettles. But did you ever hear of a poker made of cast iron or tin? You certainly have not. A poker made of tin would bend too easily and one of cast iron would break against the side of the stove.

Different materials have different characteristics and qualities. One is attacked by acids, another by water, another has to be handled carefully and another can stand the roughest treatment. When something is to be made we must first think what kind of life it is going to have, whether it will be a peaceful one or will it, from the very first day of its existence, have to stand being knocked about? Will it have to associate with water or acids or what? This must be kept in mind when selecting the materials for making any article.

What Material is the Strongest and What the Weakest?

We all consider iron a strong and durable material. That is why great bridges and railway stations are built almost entirely of iron. But this strongest of materials is also one of the least durable. The great railway bridge which does not bend under the weight of hundreds of heavy cars is attacked by moisture, rain, mist. The more moisture there is in the air the sooner the iron is ruined by rust. Rust is the disease which insidiously destroys the strongest iron structures. That's why so few things made of iron have come down to us from antiquity. It is easier to find a gold bracelet or finger ring formerly belonging to some Egyptian Pharaoh than a common iron sickle of one of his numerous subjects.

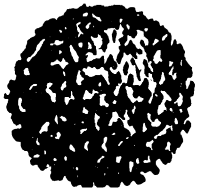
Perhaps many years hence scientists will not find in the ruins of our cities a trace of our iron structures. They will all have turned to rust and rotted away, like the bones of the men who made them.

But what is this terrible disease? And is there no cure for it?

What happens to a knife or fork if it is not thoroughly dried after it is washed? It rusts. Every house-

keeper knows that. That is, it is moisture which makes iron rust.

Once some divers went down to the bottom of the ocean for a ship which had sunk a year and a half previously. On board the ship they found some cannon balls which were so eaten up with rust that they



could be cut with a knife. You can see from this what the water had done to them.

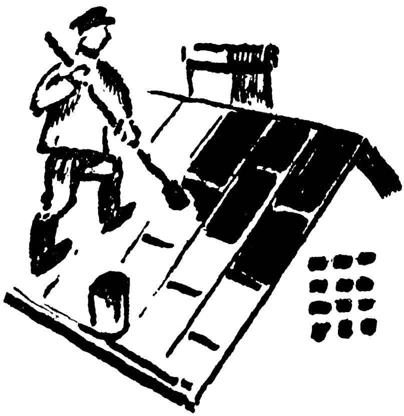
How can Iron be Protected from Moisture?

It must be wiped dry.

But it can't always be wiped. There are things which can't be kept dry all the time. A teakettle, a bath tub, a water pail must be wet whether we like it or not. And it would be still harder to keep an iron roof dry. You couldn't very well wipe it off with a towel after every rain.

Even in very dry weather iron will rust, though not so fast. For, you know, there is always moisture in

the air. Everyone is taking the moisture out of the air all the time, but there is no such thing as absolutely dry air. It is always absorbing water everywhere—from the freshly scrubbed floor, from wet sheets hung out to dry, from puddles left by the rain.



The only way to prevent iron from rusting is to coat it with a layer of some other substance which will keep the moisture out. With some kind of oil, sunflower oil, for instance. The oil protects the iron from water and keeps it from rusting.

But this is not what is ordinarily done. In place of oil an oily paint is used. That is, a paint made by mixing with boiled oil. Boiled oil is better than raw oil because it dries more quickly. The coat of paint

on the iron dries out and becomes hard. This hard coat will naturally be better and last longer on the iron than a coat of oil.

This method is very good for roofs and also for pails. But no one would think of painting a teakettle. The boiling water would soon wear the paint off. How are we going to keep a teakettle from rusting, then?

Why Doesn't Tin Rust?

Iron and chocolate have one thing in common. You know how chocolate comes wrapped in a thin sheet of tin—tin foil or tinned paper—to protect it from moisture so it will not spoil. They often do this same thing with iron, coat it with tin to keep it from rusting. This gives us a beautiful white tin, the material of which cookie tins and tins for preserving fruits and vegetables and inexpensive tin teakettles are made.

Tin is fine for protecting iron from moisture; but better still, it protects it from acids too. Acids rust iron even worse than moisture does. Just notice how quickly a knife tarnishes when you cut a lemon with it. This is because the acid has eaten the iron. Tin isn't affected in this way. Only very strong acids affect it.

If you examine the tin in which some acid fruit is put up, you will find that it has rusted only where there is a scratch.

Now, it is very easy to coat small articles with tin, but it is expensive to coat a whole roof with it. Iron roofing is frequently coated with another metal which is less expensive than tin—zinc. This zinc-coated iron is called galvanized iron and it is even more resistent to rust than tin.

Then why don't they make saucepans and kettles and tin cans of galvanized iron?

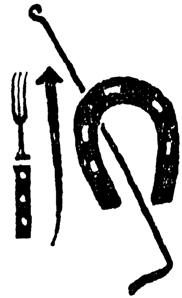
For a very simple reason: zinc, which is not at all affected by water, is very easily eaten by acids, even the weakest ones. And the zinc salts which are produced by this are extremely poisonous. To cook or preserve foods in zinc vessels would be dangerous. It is all right for things like water pails and bath tubs. They are often made of galvanized iron.

Iron has to be taken care of as if it were a living organism to protect it from rust, the deadly sickness to which it so easily succumbs. Even when it is painted or coated with another metal it has to be carefully watched. Roofs must be repainted from time to time and the rusted parts removed, as doctors cut out diseased tissues in the human body.

What are Iron Things Made of?

What a silly question! They're made of iron, of course.

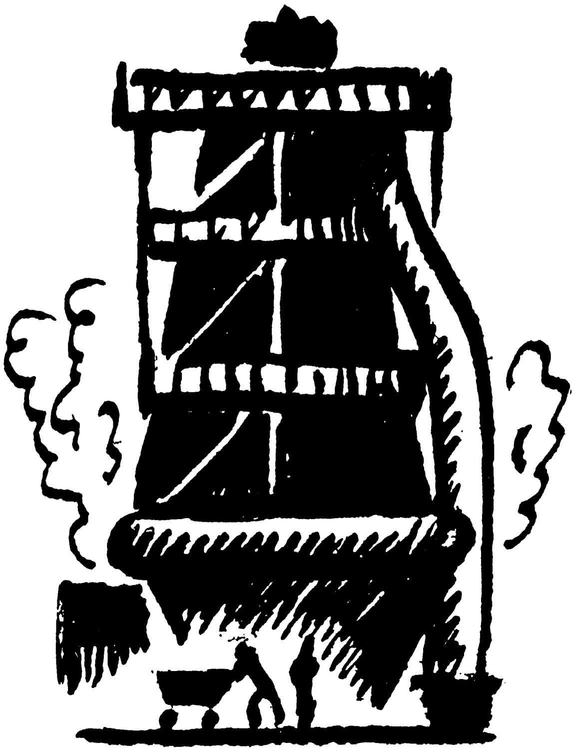
There now, you're mistaken again. All the things we call iron, forks, nails, horseshoes, pokers, are really not made of iron at all, or rather, they are not made of pure iron, but of iron mixed with carbon and other things. Pure iron, without any alloys, is so dear that a common poker made of it would cost more than its selling-price. And it would not only be more expensive, it wouldn't be nearly so good as one made of ordinary iron. Pure iron is too soft. A poker made of it would bend the first time you used it. It would be impossible to drive a nail into the wall, and a knife blade wouldn't be good for anything but a paper cutter.



Pure iron is so soft and ductile that one could make "iron paper" of it which would be lighter and thinner than cigarette paper.

The iron we are talking about, the iron we ordinarily use, always contains alloys. Of course iron isn't improved by adding just anything to it. Sulphur,

for instance, injures it, makes it brittle. Iron's best companion and most faithful friend is carbon.



Carbon and iron are almost always found together.

How does the carbon get there? In this way: Iron is obtained from an ore found in the ground. To smelt

the iron out of the ore it must be heated to a very high temperature in big furnaces. These furnaces are built like the chimney of a samovar. Ore and coke are put in in alternate layers at the top. Air is blown in at the bottom. Just as housekeepers blow on the fire in the samovar to make it burn. Only in these furnaces the air is not blown in with the mouth, naturally, but by means of powerful air pumps.

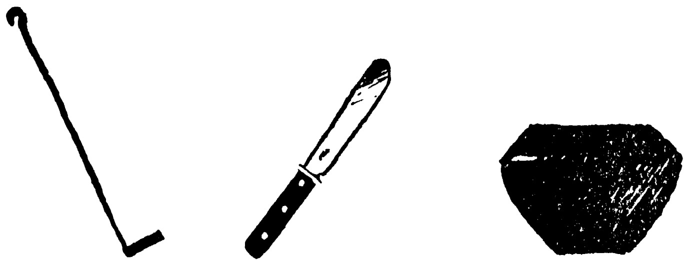
The coke gets white hot and burns up. The iron is smelted out of the ore and trickles down to the bottom of the furnace. The white hot molten iron dissolves the carbon, just as hot water dissolves sugar. So we don't get a pure iron in the furnace but a strong solution of carbon in iron. This is called pig-iron (or cast iron) and contains a very large amount of carbon from the first moment of its existence.

A part of this carbon can be burned out if air is blown on the molten iron. This is the way steel and wrought iron are made from pig iron.

What is the Difference Between Cast Iron and Wrought Iron and Between Wrought Iron and Steel?

The character of iron depends chiefly on the amount of carbon in it. If you compare an iron poker, a steel knife, and a cast iron kettle they will seem to

be made of entirely different materials, they are so unlike. Take the wrought iron poker: it is rough and ugly looking, with a dark, scaly coating. You can bend it and it will not straighten out. You may knock it about as much as you please, it won't break. It is



not afraid of hard work. Poking the wood and coal about in the stove is nothing to it.

Now look at the steel knife: it is beautiful, shiny, sharp. If you bend it it springs back of itself, because it is elastic. But don't bend it too far or it will break. If you used the knife to do the poker's work it would break into bits. But in its own field it is a master hand. If you have something to cut or plane or split, the knife can do it for you.

The cast iron kettle is grayish, almost black, from the large amount of carbon in it. It is brittle. If you hit it with a hammer it will break into bits. You can't poke the fire nor split kindling with it. But

when it comes to boiling something for dinner, that's right in its line.

These three articles are not made in the same way. The poker is hammered out from a piece of hot wrought iron. Wrought iron, when heated red hot, become soft and pliable and can be forged, that is hammered into whatever shape is required.

The knife blade was also forged. But after it was forged it was again heated red hot and plunged into cold water. This made the steel very much harder.

Cast iron cannot be forged. When it is raised to a very high temperature it melts at once and becomes liquid. Wrought iron and steel behave in a very different way. They become soft before they reach the melting point. And it is while they are in this soft state that they can be made into any desired shape —forged, stamped, rolled into long strips.

The kettle was not forged, it was molded, that is, the molten iron was poured into a form made of dry earth and allowed to cool.

It is the carbon in the iron which makes all these differences. Lots of it in cast iron, less in steel, and least of all in wrought iron.

You can easily tell how much carbon there is in the steel of your knife blade. Hold it against a grindstone and see what kind of sparks come off the edge

of it. If the sparks branch out like the branches of a tree, it contains a large amount of carbon. The more the sparks branch out the more carbon there is. But if the sparks go out in straight lines of fire without any branching at all, this shows that the blade is made of wrought iron instead of steel.

You can often tell what things are made of by just some such simple test.

SICK BUTTONS

Tin protects iron from its special disease, rust. But tin, too, is sometimes attacked by a disease, though not very often. But when this disease does occur it is a real plague. If it appears anywhere it spreads rapidly and infects all tin articles in its vicinity.

The last such epidemic in Leningrad was seventy years ago. Some military buttons for soldiers' uniforms were stored away in a cupboard. Suddenly a

suspicious looking rash appeared on them and soon all the buttons were covered with dark spots. People were frightened. No one had the least idea what was the matter. They couldn't save the afflicted buttons which all crumbled and went to pieces before their eyes, leaving nothing but little heaps of a grayish looking powder.

Scientists racked their brains for a long time trying to explain the cause of the strange disease. Finally they discovered it. And what do you think it was? The tin-plated buttons had caught cold! It was a very cold winter. The thermometer stood 4° below zero. The cupboard where the buttons were kept was not heated and no one knew that tin cannot stand extreme cold. It was found that tin has two forms: a powder, and the form in which we know it. Like carbon which is found in three forms: ordinary coal, graphite, and diamonds.

Tin goes to pieces at a temperature 4° below zero. Pouring boiling water over it will restore it to its former condition. But cold alone will not affect the tin, there has to be infection too. If even one little particle of this tin powder falls on a button which has been affected by the cold it is impossible to save it.

It has been discovered that other metals can get this disease too, though they do not take cold nearly so easily as tin.

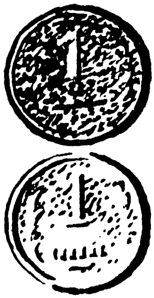
Is There such a Thing as Yellow Copper?

We have been talking so much about wrought iron and cast iron and steel that we've completely forgotten about the copper saucepans. Let's take this one made of red copper. We could say merely made of copper, for there is no other kind of copper except red copper. Sometimes people may use the expression "yellow copper," but this is not copper at all. It is brass, a mixture of copper and zinc. This is the material you see in door knobs. Brass is usually about half copper, at most not more than two thirds. The more zinc there is in brass the lighter colored it is. If it is more than half zinc the brass is almost white. You can easily tell by the color how much zinc there is in brass.

These saucepans which we are talking about are very fastidious creatures. If you don't keep them clean they soon get a coat of brownish or green tarnish. We might call this tarnish copper rust if it were not for one big difference between copper and iron.

Iron rusts clear through. But copper rusts or, as

we say, tarnishes only on the surface. And this coat of tarnish really preserves the copper from decay, like a coat of paint. That is why we have so many bronze[1] statues preserved to this day. The coat of green tarnish in which they are dressed has protected them from oxidation for centuries.



Copper coins also turn black very quickly. Their surfaces become oxidized. They can easily be made to look new and bright again by putting them into liquid ammonia. The oxidized copper is dissolved and turns the ammonia a beautiful blue color and the money comes out perfectly clean.

Brass, a mixture of copper and zinc, oxidizes much more slowly than pure copper.

And now look inside the saucepans. The inside is entirely different looking from the outside. They

[1] Bronze is an alloy made by mixing copper and tin.

are white instead of red inside. This is our old friend tin. It protects the copper from the acids and salts in foods. For acid and salty foods eat a copper vessel. This makes copper salts which are as bad for us as the worst poisons. That is, the tin lining not only protects the copper from the foods but protects the foods from the copper as well.

What can be Made of Clay besides Pots?

How strange it is to think that all the gaily painted bowls and jars we see for sale in the markets and pottery shops are made of common everyday clay, the clay we so hate when we have to walk along a muddy country road.

And not only bowls and jars and pots—what don't they make of clay? Bricks and porcelain figurines and plates; the blueing used in laundering clothes, cement, and paint. But the most amazing thing is that every kind of clay contains aluminum.

Scientists only learned about this light white metal

very recently, yet now you can find an aluminum saucepan in almost every kitchen. And no wonder. For aluminum doesn't rust like iron and is not attacked by the acids in foods. True, it is attacked by soap and soda, but this isn't a very serious defect.

They often call aluminum "clay silver." But it is a far cry from silver to aluminum. The white color of aluminum soon turns gray, because when exposed to the air it is covered with a layer of oxide which spoils its looks, although it really protects it from serious oxidation. This coating is absolutely harmless, unlike the oxide on copper.

So aluminum is not a suitable material to use for articles which must always look bright and shining. But it has one advantage over silver and gold and steel—it is very light, only a third as heavy as iron. And this is very important in the construction of aeroplanes which must be as light as possible. Aluminum makes a very valuable alloy with a number of other metals. Duraluminum, for instance, an alloy of aluminum, magnesium, copper, and manganese, is three times as light as steel of the same strength.

And to think that the common clay of our roads is an almost untouched source for this excellent,

valuable metal! So far aluminum has been obtained from other ores, boxite and criolite. It is not practical to get it from clay as no economical method of extracting it has yet been found.

Porcelain is also made of clay—a specially pure *white clay* called kaolin, not so commonly found. We have none of it here in the north. Our most common clay is found in the Leningrad district. It is an ordinary clay good for brick making. There are a number of other substances in this clay but some of them are easily separated out.

Try putting a piece of clay in a glass and mixing it with water. All the heavy parts will settle to the bottom while the clay will remain in the water forming a cloudy liquid. Pour this liquid off into another glass. The light particles of clay will gradually settle to the bottom until the water becomes almost

clear, and on the bottom of the glass there will be a layer of clayey slime. In the other glass we shall have a collection of pebbles, coarse limestone, and grit.

What happened in these two glasses has been going on in nature from time immemorial. In place of the little ball of clay mixed with water, imagine a mighty granite mountain range. In place of the water you poured into the glass, picture a roaring mountain torrent, rushing boisterously down to the valley. No matter how strong the granite is it is affected by water and wind. As time goes on the granite range is dissolved into sand and clay. The mountain torrents carry the sand and clay along with them. The little pebbles and coarse grit settle first. The clay and fine sand settle later, lower down where the current is not so strong.

So a layer of clay is formed at the bottom of the river. Now it may happen that the river dries up or changes its course but the layer of clay remains. And the only thing which tells us of the rivers which once flowed where now no trace of them is left, is the little heap of pebbles, rounded and smoothed by the water —little pebbles like those we found in the bottom of our glass.

There are other foreign bodies in clay besides sand and pebbles—iron rust, for instance, which gives the

clay a reddish or yellow color. That is why bricks are red although they have not been painted. On the contrary, clay is used in the manufacture of certain paints, for example, ochre, which is a yellow or red clay in which there is a large amount of iron rust.

It isn't so amazing that granite can be changed into sand and clay as that clay can be turned into the most ordinary kitchen pot. Just compare a piece of clay with a clay crock. The clay is crumbly and *breakable*. *The crock* is firm and strong. The clay can be dissolved in water and turned to paste. You can do anything you like with clay—model it into different shapes, roll it out flat, or twist it into rolls. You can't change the shape of the crock unless you break it into bits.

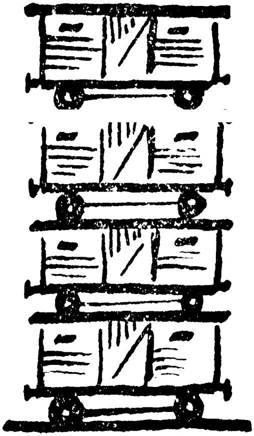
The best way to learn all about this is to try making a pot ourselves. It isn't so very hard to do. As the proverb says: "It doesn't take a god to make a clay pot."

What Can we Learn from a Common Kitchen Crock?

To make a crock the clay must first be prepared by mixing the dry clay with water.

But we are not going to take anything on faith. We shall ask: "Can't we get along without water?"

And sure enough we can. A press has been invented which makes all kinds of clay articles, such as crocks, bowls, and tiles, without a single drop of water! The dry clay is put into a steel mold and pressed with a steel stamp. A tremendous pressure is



required to do this—200 atmospheres. Do you know what that means? To get this amount of pressure on this book you would have to pile four freight cars on it, one on top of the other, all loaded to the top. But we have no such press and it is obviously quite impossible to press as hard as that with our hands.

Just as oil diminishes friction in machines, water diminishes the friction between the different par-

ticles of the clay. Now molding consists merely in getting the particles to arrange themselves in the way we wish them to be. Furthermore, water doesn't allow them to separate. It holds them close together.

But that isn't the whole story. When we make a clay article by pressure we not only give it a certain form, but also squeeze it together and make it more compact. Water helps us do this too. When an article made of wet clay dries the water evaporates. This brings the particles of clay closer together and the article becomes more compact. A clay brick will shrink at least a fourth in drying.

But this has its disadvantages too. A clay vessel often cracks when it dries, like the bottom of a dried-up pond. You have doubtless seen the cracks in clayey soil which has dried up after a rain. They remind one of those great fissures which form on the surface of the earth when there has been an earthquake. And I dare say that to some little ant it does seem a great abyss, and he shivers with terror as he looks down into it.

To keep the clay from cracking they add sand to it. The grains of sand scattered about in the clay strengthen it, like a strong framework or skeleton, and prevent it from shrinking too much.

Now that we have got all these facts straight we can go to work. Get a piece of clay (from some stove setter) and add some water to it, about one third as much water as clay, and knead them together. If too much water is added the clay will stick to your hands. If too little, it will not hold together.

Add a little very fine sand to the wet clay. Knead it in well so that the sand will not show. Now you're ready to model your little pot.

You may not succeed the first time. You see, there are different kinds of clay. One requires more sand, another less. The only way you can find out the quality of your clay is by experimenting. If one pot doesn't turn out well, make another until you get what you need.

Here's your pot all made! But how crooked and ugly it is! If you look at it from the top you can see that it isn't round. It is all swelled out on one side like a man with a toothache!

And it would be hard to make it any better. For it is no easy thing to measure with your eye so that all parts of the side shall be equally distant from the center. It's like trying to draw a circle without a compass.

Potters have a special work table for molding clay

vessels. A potter's work bench is merely a round board which turns on an axis. It is set in motion with the foot. The potter then holds the piece of clay in the middle of the board and, putting his thumb inside the clay, holds it with the rest of his fingers on the outside. As the clay turns round it rubs against the potter's fingers and is formed into an even round wall. It is as if we described a circle by holding the compass still and turning the paper round. The compass is the potter's hand, which is stationary, the turning paper is the circular board of the work bench.

Now our pot is done—such as it is—and we shall put it on a board to dry for a couple of days. When it is dry it must be fired. If it isn't fired it will not hold water. For, you see, if it isn't fired the water will soften the clay up again. And a fine pot that would be if it softened up and turned to paste the first time you put water in it!

Put your pot into a furnace of red hot coal. Here you may have an accident for if the pot is not thor-

oughly dried it will go to pieces. The water which is left in the clay will be turned to steam by the heat and as steam occupies more space than water it will burst the walls of the pot and escape. To prevent this the pot must be thoroughly dried before firing.

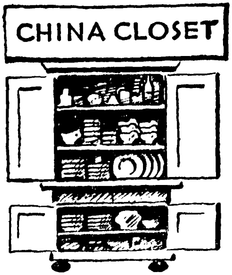
While the pot is in the kiln let's see why we put it there. During the firing the particles of clay are cooked and fused together. That is, the fired pot is no longer made of separate particles which can move about freely if it is wet again, but of a compact porous mass. It will never again be possible to make clay of it.

In a few hours our pot will be finished. It will be of a brick red color and we may now fill it with water without being afraid it will melt. But it still has one great fault. Water can leak out through it, though very slowly. This is because there are pores between the particles of clay which have been fused together and the water oozes out through them.

If you examine a real kitchen crock, not our amateur one, you will see that it is coated on the outside with a transparent film. This film, or glaze, as it is called, closes the pores in the crock, just as glass closes the windows of your house. If we could shrink up small enough to get inside the sides of the crock we should find ourselves in a tortuous craggy corri-

dor, winding about among the different particles of which the sides are composed. At first it would be pitch dark. But, look, at last there is a light! We hurry towards the exit but stumble into a transparent but impenetrable wall! We turn back and follow another path, turning first to the right then to the left, but everywhere we find the same barrier. All exits from this stone prison are hermetically sealed with a transparent glaze.

The simplest way of glazing a clay vessel is to mix salt and sand with water and cover the outside of the pot with this mixture before firing it. The salt fuses with the sand and clay and forms a glaze.



STATION FIVE
THE CHINA CLOSET

The Kitchen Crock's Aristocratic Relatives

THE saucepan and the aeroplane aren't the only relatives of which the earthenware crock can boast. It has other cousins living right here in your house, in this very room. But they don't live on the kitchen shelf. They live in a fine big house called the China Closet.

Here they are—all drawn up as if for a dress parade, the dinner plates at the head of the line. Next come the soup plates, then the teacups and saucers, and

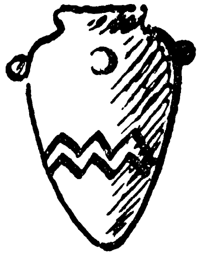
after them the sugar bowl, with one of its handles missing, and the teapot with a broken spout. All of gleaming white china.

Grandest of all is the handsome mug of real porcelain, decorated with a pink mill on a pink river, with a pink fisherman fishing with a pink fishing rod.

How can there be any connection between it and the humble old earthenware crock, with its cheap dark-colored glaze? Nevertheless, if there had never been a crock there would never have been a china mug. People would never have learned how to make porcelain if they hadn't first learned how to make clay pots.

Who Invented Porcelain?

Here and there along the coast of the maritime countries, Denmark, Sweden, and France, there are long flat earthen ramparts or dunes, near the shore.



When these mounds were opened and examined they were found to contain great heaps of all kinds of refuse: fish bones, mussel shells, skulls, stone knives and trowels, bone hatchets made of reindeer horn.

Evidently primitive peoples had lived here at some time and had been in the habit of throwing all their kitchen scraps and broken utensils into a heap near their dwellings. In the course of time these scrap heaps grew to real mounds, several hundred miles long.

In these "kitchen mounds" were found, among

other things, broken bits of clay pots. The pots of these primitive people didn't look much like ours. They were not glazed, they were not flat on the bottom but pointed or rounded. Still they were really and truly earthenware pots.

It was not until many thousands of years later that porcelain appeared. And no wonder, for you can easily see that a china cup is a much harder thing to make than a clay pot. It was the Chinese who first learned to make porcelain, seventeen hundred years

ago. But they didn't really achieve any great success in it until about the fifteenth century, under the Ming dynasty.

Chinese porcelain sold in Europe for its weight in

gold. No one knew how to make it until at last a certain alchemist succeeded in divining the secret of the Chinese. The same thing happened in the case of porcelain as with the other Chinese inventions, gunpowder and printing. Europeans had to invent them anew because the Chinese didn't share their knowledge with any other people.

It is said that gunpowder was invented by Berthold Schwartz. Gutenberg was the inventor of printing. The man who discovered how to make porcelain was Boettger.

Boettger was the court alchemist of the Saxon King August the Strong. Alchemists thought that such metals as copper, iron, and lead could be turned into gold if they could be fused with the "philosopher's stone." For years and years they hunted for this stone, which existed only in their own imaginations. And the alchemists weren't the only ones who believed in its existence, either. Kings, who were always needing money, hired alchemists to work for them, hoping they would be able to fill up their empty coffers with this artificial gold.

To keep the court alchemist from running away and going into the service of some other king, he was usually kept shut up like a prisoner. Sometimes a

king would get tired waiting for the promised riches and order the unfortunate scientist put to death. Whether in mockery or as a special tribute of respect to science, I don't know, but at any rate they used to *hang alchemists on special, gilded gallows instead* of the ordinary kind. I think you will agree with me that one would be quite as dead if hung on a gold-plated gallows as on any other. Pills do their work even though they are sugar coated.

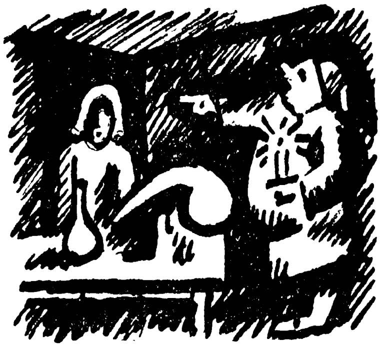
In their search for the non-existent philosopher's stone the alchemists accidentally made real discoveries. This was the case with Boettger. When he was only fourteen years old he happened to find a manuscript about the philosopher's stone, telling how to make gold. From this time on he could think of nothing else. However, perhaps he would never have became an alchemist, if he had not happened to have a laboratory handy. He was an apprentice boy in an apothecary's shop. Every night, after the apothecary, Zorn, had gone to bed, his young apprentice worked secretly at his experiments in alchemy.

Once when he was wholly engrossed in his work, the door opened suddenly and Mister Zorn, in bath-robe and night cap, came into the room.

"What are you doing there, you good for nothing? How dare you use that big retort without permis-

sion? Your wages for a whole year wouldn't pay for it if you should break it!"

"I am trying to make gold," said young Johann timidly.



"Gold! You rascal! You'd better be learning how to make sticking-plaster! I don't need an alchemist. What I want is an apothecary's apprentice. Pack up your things and go home. Tell your father to beat this nonsense out of you!"

Boettger went sadly home carrying on his back his little knapsack in which were a pair of ragged trousers, a few shirts, and the precious manuscript, which promised him riches and fame.

He did not receive a very warm welcome at home. Although his father was an engraver of coins, money was a scarce article in their family.

In a few months Boettger was forced by poverty to return to Zorn. He had to promise that he would never bother with alchemy again. But a passion for alchemy is as bad as a passion for gambling, and he again began to work at his nocturnal experiments. But this time he took greater precautions.

But Zorn was on the lookout too. And one unfortunate night the apothecary again caught him in the act and chased him out of the shop without giving him a chance to explain.

Boettger was in despair. He daren't go home again. But just at this point fate took pity on the homeless alchemist. By chance he became acquainted with a distinguished aristocrat, Prince von Furstenburg. When he heard about the experiments of the sixteen-year-old scientist, the prince took him to his palace and built him a real laboratory.

Now Boettger was in luck. They dressed him in fine clothes, gave him money and a grand place to live. When Zorn heard about it he bragged to all his customers about how his apprentice had become a famous alchemist. And they would reply that it was no wonder that the boy had learned all sorts of wonderful things from such a teacher as Zorn.

The years passed. Boettger began to grow a beard.

And still nothing at all had come of his experiments. The prince, who at first was so fond of him, began to suspect that he was nothing but an impostor. And swindlers were severely dealt with in those days.

Boettger tried to run away but they caught him and forced him to continue his work. When he was working in the apothecary's shop he had been punished for making experiments, and now they threatened him with the severest punishment because he didn't want to make them any more.

Finally he was ordered to write down his recipe for making gold. Then he really did have to become a swindler. He wrote down the most elaborate, complicated directions which, from beginning to end, were nothing but pure nonsense. But he didn't fool the prince. His trick was discovered and the king ordered him sent to prison.

And now Zorn wasn't so ready to brag about his apprentice.

"I always said that Boettger was an impostor and a rascal, and that he would end on the gallows," he said to his customers, to whom he had lately been singing quite another tune.

But fortunately Zorn was mistaken this time too. Boettger was lucky again. He found another protec-

tor, Count Tschirnhaus. He suggested to the king that Boettger should be given the task of finding out how to make porcelain, which at that time was more valuable than gold. Just lately King August had presented the King of Prussia with a handsome service of china, consisting of forty-eight pieces.

Boettger was successful in these experiments and made some porcelain of Meissen clay. True, it was brown not white, but it was porcelain, nevertheless.

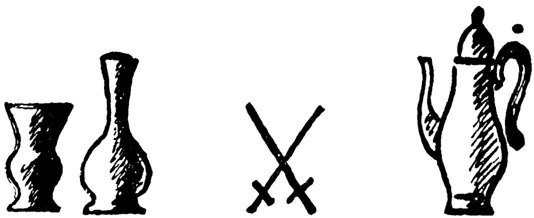
The inventor was richly rewarded. But they didn't give him his freedom. They proclaimed the method of manufacturing porcelain a state secret and kept Boettger and his three assistants under close guard, as if they were criminals.

At first porcelain ware could be found only in palaces. The Saxon king sent gifts of Meissen vases to other kings. But in 1707 it was first put on sale in the market of Leipzig. A big factory for the manufacture of porcelain was set up in the castle of Albrechtsburg in Meissen and here Boettger succeeded at last in producing white porcelain.

Meissen ware, which can easily be recognized by the trade mark, two crossed swords, soon became famous all over the world. It was very hard to tell the difference between it and real Chinese porcelain.

Boettger spent many years as a prisoner in the

castle of Meissen. He was refused nothing except his freedom. When he was quite an old man he again tried to run away. He managed to get into secret



communication with the Prussian court with the idea of making his escape. But he didn't succeed. His secret was discovered and he was arrested and condemned to death.

But Boettger had one more stroke of luck—his last. He fell ill and died in prison and so escaped execution.

THE SECRET OF THE MANUFACTURE OF PORCELAIN

What was this state secret which the prison keepers of Meissen castle guarded so jealously? Precisely what is the secret of the manufacture of porcelain?

It is not just one secret, but many. The first one is that a special kind of clay, very white and pure, must be used. They say that Boettger found this clay quite

by chance. Once when he was powdering his curled wig he noticed something unusual about the powder. It didn't seem to be powder at all but some kind of very pure clay. And it turned out that it really was a clay which was found in large quantities in the neighborhood of Meissen castle. Boettger tried making porcelain of this clay and it turned out successfully.

Perhaps this story is not true. Perhaps this wasn't at all the way it really happened. But at any rate half the work was done when he had the good fortune to obtain a suitable clay.

The second task was also a hard one: to find pure white sand and good mica or feldspar. He had to have the sand just as in making pottery so that the clay would not crack when it dried. And the mica or feldspar was added to make the clay more fusible.

The third secret was that both the sand and the mica or feldspar must be pulverized and the coarser particles separated out by precipitation just as we did when we precipitated the clay in our glass of water. The larger particles which settle to the bottom first must be discarded. All that can be used is the very fine slime which settles to the bottom very slowly. The clay too must be precipitated as it may have coarse foreign bodies in it.

These fine particles of clay, sand, and feldspar are then mixed into a paste. This paste is made into the desired form on a potter's wheel. There is nothing so very difficult about the molding and drying but the

firing of porcelain is an entirely different matter from that of earthenware. It requires the greatest skill.

It must be fired twice, first only slightly. The second time, it must be fired at an extremely high temperature—until it is almost at the melting point. But what do you think happens then? The vessel, so painstakingly molded, is likely to settle from the intense heat and get crooked and out of shape. So all kinds of boxes and casings have had to be devised to keep them in shape. These, like crutches, help the dishes to stand up and not tip over to one side. Even so, much china is spoiled in the kiln.

There is still another secret which must be known. If the glaze is not carefully wiped off the lower rim, where the bottom touches the support, a very unfortunate thing happens—the glaze melts and glues the vessel to the support.

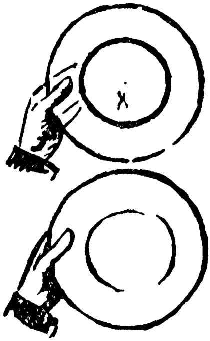
Why must porcelain be fired at so high a temperature? Wouldn't it be better to fire it less? That's just the point. Firing it slightly doesn't do at all. If it is fired less you get pottery or delft ware instead of porcelain or china.

What is the Difference Between Pottery and Porcelain?

Just this: porcelain is completely fused, compact like glass, whereas pottery is porous like earthenware. The intense heat has fused all the little particles together in porcelain. This is why it is translucent.

If you want to know whether a plate is made of porcelain or pottery all you need to do is to hold it up to the light. The porcelain will let the light shine through, pottery will not. At least the ordinary kind of pottery will not, the kind usually found in stores. But a still better way to distinguish porcelain from pottery is to look at the bottom. If the rim is glazed

this shows that it is pottery. If the glaze has been cleaned off the rim then it is porcelain.



Is there Anything in your China Closet which is made of Sand?

Take a good look at the shelves of your china

closet. What do you see there besides cups and plates? Do you mean to say that you don't see any-

thing made of sand? What about the tumblers and salt cellars and wine glasses?

Yes, glass is made of sand, common, ordinary, everyday sand, the kind children make cakes of. And not only tumblers and wine glasses. Nowadays whole houses are built of glass and iron. In London, for instance, there is a big house called "The Glass House." It is so high and covers so much space that big trees grow in its rooms just as if they were out in the open air. And this huge house stands. It doesn't fall apart, although it is half sand!

A SOLID LIQUID

In making ordinary bottle glass, the sand is put into an earthenware vessel, soda and chalk are added, and it is put into a special kiln. The earthenware vessel must be of fire resistent clay, that is, of clay which will not melt at a high temperature. When they become red hot all three materials, sand, soda, and chalk, fuse together and we get a molten glass, liquid like water.

But it only looks like water. When it cools it acts in an entirely different way. When water is cooled it remains liquid until the temperature falls below the freezing point, 32°. But the moment the thermome-

ter does reach the freezing point, the water freezes, turns into solid ice.

Liquid molten glass does not act in this way at all. As it cools it thickens very slowly. At 2192° F. it is like syrup. At 1832° F. it begins to form threads and at 1072° F. it is still more elastic. Gradually thickening up like tar, the liquid turns to a soft plastic doughy mass, which hardens into the glass we are accustomed to see.

Try to say at precisely what temperature glass melts and when it freezes. It is impossible. That is why glass is often called a "liquid solid," although at first glance this expression seems as absurd as "white soot," or "hot ice."

If glass were not a "liquid solid," if it were not plastic like dough, we could not make all the different kinds of articles which are made of it—all those big-bellied decanters, fancy wineglasses, and ornate vases.

A SOAP BUBBLE FACTORY

They say "Strike while the iron is hot." Almost the same thing might be said of glass: "Blow while the glass is hot," before it has got hard and brittle. Or, perhaps you didn't know that most glassware is blown. Yes, blown, just as children blow soap bub-

bles, only instead of a straw they use a long iron pipe, with a wooden mouthpiece.

When the molten mass in the pot has cooled off, the worker picks up a piece of the plastic glass on the end of his pipe and proceeds to blow on it. He makes

a glass bubble. Of this bubble he can make anything he wishes: a tumbler, a wineglass, a bottle, even flat windowglass. Suppose he wants to make a bottle. He puts the bubble into a mold and blows until it fills the form, touching it on all sides. When the bottle has cooled it can easily be taken out, as the mold is jointed so that it can be opened. Of course, the bottle must first be cut loose from the blow-pipe. This is done by passing a cold rod over the hot spout.

An experienced glass-blower can blow glass into almost any conceivable shape merely with the help of this simple pipe. Did you ever happen to see the

glass apparatus used in laboratories? They are all of blown glass.

Glass blowing is hard work and bad for the health. So in many factories, especially where large articles are made, mechanical blowers are used instead of human lungs. Twenty years ago a machine for blowing bottles was invented. This machine, which can be run by two workers, takes the place of eighty glass-blowers. In one day it makes 20,000 bottles.

But blowing is only one of the necessary processes in the manufacture of glassware. It must be properly cooled.

If a glass rod is held in the fire until it melts at the end and a drop of it allowed to fall into water, it will form a hard, transparent tear-shaped globule. Break off a bit of this globule and the whole thing will fly to pieces and turn into fine powder. This shows how fragile glass is if it is cooled too quickly.

To make it less fragile it has to be kept for a long time in a special kiln where it cools very slowly.

Some glassware, such as tumblers, wine glasses, and vases, are then cut into facets and ground out on a grinding stone. These facets are at first dull and lustreless. But when they are polished with emery or some other abrasive powder they become smooth and brilliant.

Very often, in place of first blowing a dish and then cutting and polishing it, they go about it in another way. They pour it into a mold, just like cast iron. Or, if the glass fuses easily and becomes plastic at a low temperature, they simply press it into the

desired shape. Molded or pressed glassware can easily be distinguished from cut glass as all the corners are round instead of sharp. This is another thing it might be well to remember, for perhaps sometime you might find it useful to distinguish an expensive cut-glass goblet from a cheap molded one.

Large pieces of mirror glass are also poured instead of blown. They make big thick sheets and afterwards grind and polish them.

It is not methods of manufacture alone which make the differences in glassware. There are also different kinds of glass. For instance, green bottle glass

is made from common yellow sand mixed with soda and chalk. There is a large quantity of iron rust in this yellow sand which gives it its yellow color. This yellow color becomes green in the firing kiln. That is, the greenish tinge is an infallible sign of the presence of iron in the glass.

For white window glass a whiter sand must be used. And for the manufacture of the highest grades of glass, a pure white sand is mixed with potash in place of soda, and with lime or red lead in place of chalk. This gives a heavy glass which gleams like a diamond. It is called crystal.

NON-BREAKABLE GLASS

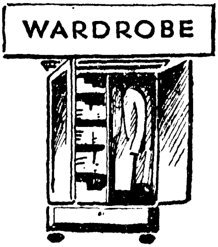
But no matter what else may be used in the making of glass, the one thing you can't get along without is sand. It has long been known that sand is the essential ingredient, but the difficulty was to get pure sand to melt. It was not until twenty-five years ago that they succeeded in doing this. It was found out that anything made of molten sand or quartz[1] was very much stronger than if made of glass. It could be heated red hot and plunged into cold water without any bad effects. However, articles made of quartz are still too expensive as they have to be smelted in spe-

[1] Quartz is sand in the form of rock instead of tiny grains.

cial electric kilns which use an enormous amount of electric power.

Quartz is the glass of the future.

During the war a new kind of glass was brought out in America, called "Pyrex." This glass does not crack even when raised to a temperature of 392° F. and suddenly cooled by being plunged into ice water.



STATION SIX
THE WARDROBE

The Last Stop

Our journey is nearly ended. Here we are at the last station, the wardrobe where we hang our clothes and put away our linen.

There are different kinds of wardrobes—giant ones, half the size of the room where six people can hide when one is playing hide-and-seek. Dwarf ones where not even the very tiniest child could hide. There are fine ones with mirrors on all the doors, and plain ones without any mirrors at all.

The wardrobe at which we have arrived is neither

very large nor very small. It has separate compartments for costumes and for underclothes. It has a mirror in the door, also not so very large and not so very small. Before we look inside the wardrobe let's talk a bit about this mirror.

THE HISTORY OF THE MIRROR

In ancient times, before there were any glass mirrors, convex metal plates were used instead. They were made of silver or some alloy of copper and tin. But these metal mirrors tarnished very easily when exposed to the air.

At last someone had the idea that the metal surface could be protected from tarnishing by covering it with a layer of glass, just as we put glass over photographs to preserve them. The result was a glass mirror.

For a long time mirrors were made by attaching a sheet of tin foil to a piece of glass and pouring quicksilver on it. The quicksilver dissolved the tin. And this solution had a remarkable quality—it adhered tightly to the glass.

The glass had to be slightly tilted so the excess quicksilver would trickle down. It took a whole

month to get the mirror covered with an even layer of metal.

A scientist, Liebig, proposed another, better method. A solution of silver is poured on the mirror. The silver gradually settles and in about half an hour the mirror is covered with a gleaming coat. The silver coat is then covered with a protecting coat of paint.

This method is better because it does away with the use of the poisonous quicksilver. And the mirror is brighter too. If a quicksilver and a silvered mirror are placed side by side, one can see at a glance that the quicksilver one is distinctly darker. A 25-candle power electric light seems like a 16-power one in a quicksilver mirror, it loses so much of its light.

The manufacture of mirrors doesn't seem to be so complicated a process, yet three hundred years ago there was only one city in the world which was able to produce them—Venice. The Venetians kept the art a secret. They had a law that anyone who dared to disclose the secret to foreigners should be put to death. The government decreed that all mirror factories must be situated on the isolated island of Murano, and no foreigners were allowed to set foot on this island.

At one time there were forty large factories on the island of Murano, employing several thousand men. France alone imported two hundred cases of mirrors annually. Besides mirrors these factories made white and colored glassware which was famous all over the

world. The delicacy and exquisite workmanship of these Venetian goblets and vases is amazing. It is hard to believe that all these intricate petals, leaves, and stems can be made of such fragile material.

The skillful artisans of the island of Murano were held in the highest esteem in the republic of Venice. It was quite as dignified to be a glassworker as to be a courtier. The island was governed by a council chosen by the glassworkers. The *sbirri* (police) so dreaded by all the inhabitants of Venice, had no power over the citizens of Murano. There was only one limitation to the freedom of these glassworkers. They were forbidden, under penalty of death, to

visit any foreign lands. Not only the fugitives themselves, but their families as well, who were left at home, were threatened with dire punishment. But in spite of all this the Venetians did not succeed in keeping their secret.

Once the French ambassador in Venice received a secret letter from Paris which set him to thinking very seriously. The letter was from the all-powerful minister Colbert. He ordered the ambassador to find workmen immediately for the king's new mirror factory. In those days what they called factories were merely large workshops which differed from the smaller ones only in the number of workers employed. This was before the days of machines.

The ambassador knew how hard it was to lure workers away from a mirror factory in Murano. He understood perfectly what was meant by that paragraph of the Venetian law which said: "If any glassworker takes his trade to any other country, he will be ordered to return. If he does not obey, his relatives will be imprisoned. If he is still unwilling to return, secret agents will be sent to kill him."

And if he did succeed in enticing some worker away, how could he conceal what he had done? For it would not do for an ambassador to violate the laws of the country in which he was a representative.

That very evening a covered gondola was moored at the ambassador's house, which, like all Venetian houses, was situated on the bank of a canal. A short,

thickset man, wrapped in a black cape, got out of the gondola and went into the house. It was several hours before he came out again.

From that time on this mysterious stranger was often at the house of the ambassador. If it had been possible for anyone to peep into the tightly locked office of the ambassador he would have seen the famous French nobleman in animated conversation with an ordinary looking man. This man was the owner of a small shop on the island of Murano.

No one knows what the nobleman and the shopkeeper talked about. The only thing that is known is that in about a week or two the French ambassador sent a courier to Colbert with a letter saying that four glassworkers had agreed to run away to France and that everything was ready for the flight.

A few more weeks passed. One dark night a boat carrying twenty-four men, armed from head to foot, landed quietly at the island of Murano. Out of the darkness appeared four men accompanied by the shopkeeper whose acquaintance we have already made. A few words were exchanged, there was a little stir about the boat, the splash of oars, and the boat was off, carrying the four Venetians to far-away France.

The shopkeeper went home hiding under his cape a bag containing 2000 lire—his profit on the transaction.

By the time the flight of the glassworkers became known in Venice they were already in Paris busy making mirrors. The Venetian ambassador tried in vain to find out where they were. They were so well hidden that it was impossible to find them.

And this wasn't the end either. In a few weeks a second party of glassworkers, again four men, ran away from Venice under the very noses of the coast guards.

The Venetian government, dissatisfied with their ambassador in Paris who could not find out where the king's factory was, appointed a new ambassador, Chivistiniani.

Chivistiniani soon found the fugitives and inveigled them to his house. He didn't dare go into the king's factory. He persuaded some of the fugitives to return. But Colbert was not napping either. He used every inducement to keep the Venetians in France. He gave them palatial homes, paid them enormous wages, granted their every wish, gratified their every caprice. He helped their families who were threatened with death to escape from Venice. The Venetian government sent out search warrants for the wives and children of the "criminal glassworkers," but not a trace of them could be found.

In vain Chivistiniani offered the fugitive glassworkers amnesty if they would return and, in addition, 5000 ducats apiece. They wouldn't leave Paris where they were living in such grand style.

They forgot entirely about the terrible law which threatened them with death.

In January, 1667, a year and a half after their arrival in France, the very best artisan of them all died suddenly of poison. Three weeks later another one, especially skilled in the blowing of glass for the mirrors, died. The doctors said that his death had been caused by poison.

At about this time two glassworkers in Venice who

had tried to run away to France were imprisoned and killed. Terror seized the artisans who were working in the king's factory in Paris. They began to beg to go home. Colbert no longer tried to prevent it. All

their secrets were now known to the French. And they were drawing extravagant salaries. Work went on without interruption in the royal factory. Beautiful mirrors of French make began to decorate the palaces of Versailles, Fontainbleau, and the Louvre. The ladies of the court powdered their faces before the new French mirrors and not one of them fancied

*she saw in her mirror the image of the Venetian glass-*worker who had made her mirror—and paid for it with his life.

What is Inside our Wardrobe?

Come now, we'll take a look inside the wardrobe. There you will see a remarkable thing which I dare say you never heard of before: clothes made of air. And this will give you the answers to three of the riddles I gave you at the beginning of our trip.

Why do we put a damp cloth over woolens when we press them?

Why does an overcoat keep you warm?

Which is warmer: three shirts or a shirt three times as thick?

Why do Clothes keep us Warm?

First of all we must ask: Is it true that clothes do keep us warm?

As a matter of fact the overcoat doesn't keep one warm. It is the wearer who keeps the overcoat warm. And how could it possibly be otherwise? An overcoat isn't a stove.

Well, you ask, do you mean to insinuate that a person is a stove?

Precisely that. Don't you remember that we learned that the food we eat is fuel which we burn up inside our bodies? We don't see any fire from it. The only way we know that there is fire is by the heat we feel in our bodies.

We must keep this heat. We build our houses with thick walls so as not to have to heat up the whole out-of-doors, and in winter we put up our storm windows and put felt round the cracks of the doors. We wear clothes for the very same reason. In place of warming up the air in the room or out-of-doors with our bodies, we warm our clothes and they keep the heat near us. Our clothes do, of course, lose some of the heat, but very much less than our bodies give off.

That is, we let our clothes get cold instead of ourselves.

Which is warmer, three shirts or one shirt three times as thick?

Three shirts are warmer.

It isn't so much the shirts themselves as the air between them that does the work. Air is a poor conductor of heat. The more air there is between the shirts, the thicker the layer of air which protects our bodies from the cold. Three shirts give us three gar-

ments of air. If there is only one shirt, no matter how thick, there is only one air garment.

Can we Build Walls of Air?

Why do we put up storm windows in the winter? To form a wall of air between the two window sashes. An air wall keeps the heat in, does not allow it to escape from the room. That is, two walls act in just the same way as two shirts.

Scientists have discovered that an air wall keeps in the heat even better than a brick one. So they have now begun to make hollow bricks. These bricks look like rolls with the soft inside part taken out of the crust. Houses made of these hollow bricks are much warmer than those made of solid bricks. Why? Because they are half air.

Why is it Bad for us to Wear Wool in Summer?

Because wool is too hot.

Yes, but that's not the only reason. Wool has a serious fault. If it gets wet it dries very slowly. Therefore in warm weather it retains the moisture thrown off by our bodies. This is both unpleasant and injurious. It is better to wear cotton or linen clothes in summer. They dry more easily and are better conductors of air.

Why do we Wear Underclothes?

If we put our outside clothes next to our naked bodies we should feel the cold more because there would be no extra layer of air around the body. But it is not for warmth alone that we wear underclothes. The chief reason is that they can be washed oftener than our outside garments. Wool, for instance, doesn't stand boiling. If it is boiled it mats and becomes thick and rough like felt. This is because its threads are not smooth like those of linen and cotton, but scaly. When it is boiled one thread catches on another with its scales, and they all get so tangled up that they can't be straightened out. Wool should not be heated to more than 140° F.

For the same reason woolen garments should not be dried by a hot stove or ironed with a very hot iron. Woolen material should always be covered with a damp cloth when pressed with a hot iron.

Garments of linen or cotton are not injured by

heat. That is why underclothes which can be washed and ironed should always be worn under woolen or knitted garments.

A GUIDE BOOK TO THE ROOM

Now we have finished our journey. We have gone only some twenty steps. But how much we have seen, how many riddles we have solved!

Travelers usually have a guide book, that is, a little book in which are descriptions of the rivers, lakes, and seas along the route, the hills and mountains, the villages and cities they will visit. What streets there are in the towns, what buildings and monuments. How long these monuments have been there and what they are intended to commemorate. If one has such a guide book he will not have to stop every few steps and ask some passerby what, how, and why.

This little book is such a guide book for anyone who wishes to take a journey around his room.

THE END